National Aerial Pesticide Application Manual

MILLENNIUM EDITION

Health Canada
Pest Management Regulatory Agency

Federal/Provincial/Territorial Committee
on Pest Management and Pesticides

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- The Working Group on Pesticide Education, Training and Certification;*
- Industry representatives; and
- Provincial agencies.

* The Working Group is a permanent group of the Federal/Provincial/Territorial Committee on Pest Management and Pesticides. The Working Group is comprised of one federal Pest Management Regulatory Agency representative, provincial regulatory agency members and college members. Without their dedication and commitment, this manual would not have been possible.

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PREFACE

The aerial application industry provides an important service to many areas of pest control. Aircraft have proven to be economical and efficient compared with ground pesticide applications for treating large areas quickly and for reaching remote locations inaccessible by ground equipment.

The variety of work performed by aircraft has increased over the years. Originally aircraft were used primarily for insect control. Their use has expanded to include weed and brush control, fungicide and fertilizer application, defoliation, desiccation, seeding and frost damage prevention. Aerial application has been used extensively in agriculture and forestry, and to a lesser extent, in right-of-way vegetation management and mosquito management. Individuals involved in aerial application of pesticides may work in a number of provinces and/or territories across Canada. To ensure consistency of training offered to aerial pesticide applicators as well as to increase flexibility in obtaining aerial pesticide certification/licensing, a ***National Aerial Pesticide Application Manual*** has been developed.

The ***National Aerial Pesticide Application Manual*** provides information that pertains to most types of aerial application across Canada, including agriculture, forestry, industrial vegetation management, and mosquito control, using fixed-wing and rotary-wing aircraft.

This manual, the ***National Aerial Pesticide Application Manual***, in conjunction with a provincial Applicator Core Manual are to be used as training and reference manuals for individuals wishing to become certified for aerial pesticide application. Applicators wishing to obtain a Pesticide Applicator's Certificate for aerial pesticide application must be aware of the information in both manuals in order to pass an aerial examination. Check with your provincial pesticide regulatory agency for specific information on the provincial Applicator Core Manual and pesticide certification/licensing requirements.

Completion of training using this manual does not guarantee automatic certification/licensing in other provinces and/or territories across Canada. Jurisdictions in Canada may require the completion of additional training programs before aerial certification/licensing is granted. It is advised that, prior to conducting aerial application of pesticides in other jurisdictions, you check with provincial pesticide regulatory agencies for this information.

The ***National Aerial Pesticide Application Manual*** provides information that pertains to most types of aerial application across Canada, including agriculture, forestry, industrial vegetation management and mosquito control, using fixed-wing and rotary-wing aircraft. The following general topics are covered:

- Regulations
- Labelling
- Human Health
- Pesticide Safety
- Environmental Protection
- Pest Management

- Application Technology
- Emergency Response.

Information is provided on both fixed-wing and rotary-wing aircraft. Aerial applicators are only expected to learn information specific to the type of aircraft they use. Complete aerial applicator training requires knowledge of the ground support operations, as well as flying operations, included in this manual. The information contained in this manual is applicable across Canada; however, there may be information unique to individual provinces. Be sure to review the information found in the Province Specific Information section. Note that, for each province, this information may vary; always check with provincial regulatory agencies for this information.

The contents of this manual are based on the Aerial module of the Standard for Pesticide Education, Training and Certification in Canada, published by Health Canada (1995) and endorsed by the Canadian Aerial Applicator Association (CAAA).

Aerial application can be a hazardous occupation. Knowing these hazards and safe operating guidelines is essential to reduce the risks. This knowledge, however, must be accompanied by caution and good judgement.

The expanding role of aerial application, along with increasing concerns for environmental protection, has required ongoing research and education about aerial application techniques, pest management effectiveness and environmental effects. In response, the industry has matured considerably since the early days of 'crop dusting,' and much has been done to promote both safety and efficiency in aerial applications.

New aircraft and dispersal systems have been designed. There has also been considerable research into spray drift management and spray efficacy, and a continuing emphasis on the critical issue of safety as it applies to applicators, their equipment and the environment.

Safety has been and will continue to be the number one priority in aerial application. There are few occupations where an act of carelessness or neglect can have such serious results. Pilots must develop a heightened awareness of hazardous situations, and must always conduct operations in a safe and professional manner. Mixers, loaders, flaggers and other ground personnel must also be constantly aware of the potential hazards in working around and with aircraft.

Three questions must always be asked prior to the aerial application of any material. "Will the applicator and crew be safe?," "Have bystander and environmental safety been considered?" and "Will the application be effective?" Operations should commence only when the answer to all questions is a very definite "yes."

The CAAA is the national association that represents aerial applicators in Canada. They support high standards of professionalism in their industry and provide a coordinated approach for aerial applicators to communicate with government regulating agencies, pesticide producers, training agencies and the general public. There are similar provincial organizations in some provinces.

Through co-operative efforts such as the development of this training manual, aerial applicators and regulators hope to ensure the safe use of aerial application for pest control in Canada.

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CHAPTER 1 - REGULATIONS

Goals of this Chapter

When you have completed this chapter, you should:

‘ be familiar with the federal laws affecting the use of aircraft for aerial application of pesticides.

Federal Laws

Aerial application of pesticides requires compliance with the Canadian Air Regulations (CARs).

An aircraft flown for aerial application must be commanded by a pilot who holds a commercial pilot’s licence, except for farmers who are allowed to operate with a private pilot’s licence providing they:

- restrict their applications to within 25 miles of the centre of their farm,
- own the aircraft, and
- apply the pesticide only for agricultural production.

Section 602.23 of the CARs specifies that no person shall create a hazard to persons or property on the ground by dropping anything from an aircraft in flight. However, “special operations” such as the application of pesticides are exempt.

Section 602.15 phase 2(b) of the CARs establishes minimum flying heights with an exemption for “special operations.” However, special authorization from the Minister is required for low flying over built-up areas.

Many provinces and some municipalities have regulations regarding aerial application of pesticides. Check with provincial regulatory agencies for requirements such as permits, buffer zones and public notification.

Some pesticide product labels indicate that the product can be applied aerially for certain specified uses. Some product labels indicate that no aerial use is allowed. Directions on these labels must be followed.

In the past pesticide labels were not clear as to whether or not aerial application was allowed. As of January 1, 2000, only products with use instructions for aerial application may be applied by air.

Provincial Laws

In addition to federal legislation, provincial governments may have policies or regulations regarding aerial application and the use of pesticides. Appendix A contains information that applicators must be familiar with specifically for the province that you are applying for certification in. It is advisable to contact the provincial regulatory agency as well for additional information.

Municipal Laws

In addition to federal and provincial legislation, some municipal governments may have developed policies or by-laws regarding aerial application or the use of pesticides. The applicator should be aware of such requirements and be prepared to address the issues well in advance of the application operation.

Review Questions - Regulations

1. Must all pilots operating aircraft for aerial application hold a commercial pilot's license?

2. What does "CARs" stand for and what role does it play with respect to aerial pesticide application?

CHAPTER 2 - LABELLING

Goals of this Chapter

When you have completed this chapter you should be able to:

‘ interpret the information presented on pesticide labels regarding aerial application

‘ interpret pesticide labels that provide no specific reference to aerial application.

Introduction

The topic of pesticide labels is covered extensively in the Core manual – you should be thoroughly familiar with this information.

The label is an essential source of information for the applicator. The information on the label arises from extensive field and laboratory data, which is assessed and approved during the federal registration process.

Pesticide labels are legal documents. Pesticides must be used according to the instructions on the label. If label directions are not being followed, laws are being broken. Applicators must read the label before using the product and abide by label directions.

A Material Safety Data Sheet (MSDS) provides additional information about a pesticide. The MSDS gives information about health hazards, personal safety and environmental protection. Until MSDSs are legally required for pesticides, they may not be available for all pesticides. Applicators should be familiar with MSDSs. Understanding and considering the information on an MSDS helps applicators make effective and environmentally sound decisions regarding emergency response and safe handling practices.

Label Directions for Aerial Application

Labels vary in their directions for aerial application as follows:

Labels Specifying Aerial Applications

Only products with label statements addressing aerial application are registered for aerial use. You must follow directions on these labels.

Labels with No Reference to Aerial Application or Contraindication of Aerial Application

Products with either no reference to aerial application or label statements that prohibit aerial application **must** not be applied by air.

Categorization

The aerial applicator should be aware of the federal categorization of pesticide products for use in wooded areas.

- ! Products labelled **Forest** or **Forest Management – Restricted** are registered for use on wooded areas or sites to be planted to forest of more than 500 hectares.
- ! Products labelled **Woodlands Management – Restricted** are registered for use on 500 hectares or less of wooded area or sites to be planted to forest for purposes such as insect control in Christmas tree plantations or control of unwanted plant growth in regenerating tree stands.
- ! Pesticide products with the use **Woodlands Management – Commercial** cover treatment of 500 hectares or less of wooded area and include tree nurseries or seed orchards and along rights-of-way in woodlands and forests.

Aerial applicators should contact provincial regulatory agencies regarding approvals or permits that may be required to use these products.

Review Questions – Labelling

1. If a pesticide label <u>does not</u> specify that the product can be applied by air, what does this mean?

2. Describe the terms “Forest or Forest Management – Restricted”; “Woodlands Management – Restricted”; and “Woodlands Management – Commercial”.

CHAPTER 3 - HUMAN HEALTH

Goals of this Chapter

When you have completed this chapter, you should be able to:

- describe the effects of cholinesterase inhibiting pesticides
- discuss the need for cholinesterase testing
- describe the symptoms of poisoning caused by some of the more commonly used pesticides in aerial applications.

Health Effects of Major Pesticide Groups

Chlorinated Hydrocarbons

Some of these pesticides can accumulate in the fatty tissues of humans as a result of a few large doses or repeated small doses. However, such pesticides stored in fatty tissues appear inactive and have not been demonstrated to cause chronic (long-term) toxicity problems. Very few chlorinated hydrocarbon insecticides are currently used. Some currently available include dicofol, endosulfan, and methoxychlor.

Symptoms of poisoning include:

- Moderate: headache, fatigue, loss of appetite, nausea, vomiting
- Severe: trembling, convulsions, coma, respiratory failure, death

Organophosphorous Pesticides

This group includes such insecticides as dimethoate, diazinon, dichlorvos, malathion and parathion. Many pesticides in this group are highly toxic and are readily absorbed through the skin, lungs or digestive tract. Even the least toxic of this group is easily capable of poisoning humans when used improperly. Repeated exposure of the applicator to small doses is also dangerous. Symptoms of acute poisoning occur during exposure or usually within 12 hours of contact.

Organophosphorous pesticides affect the nervous systems of humans and animals by inhibiting the action of an enzyme (acetylcholinesterase) that normally works to inactivate a specific chemical messenger (acetylcholine) as it passes from one cell to the next (synapse). (See “Cholinesterase Tests” at end of section). Since excessive accumulation of acetylcholine results in repeated stimulation of the receptor cells, it can have adverse effects on nervous system function. For example, repeated stimulation of muscle cells or fibres causes them to “twitch” or contract constantly and may result in fibrillations or muscle tremors. Overstimulation of neurons in the brain can result in mental confusion, seizures or convulsions. Therefore, prompt and appropriate medical treatment is required in the case of suspected organophosphorous pesticide poisoning.

In general, mild exposure to these pesticides at infrequent intervals is unlikely to produce toxic effects. However, there is a danger from repeated small exposures, as symptoms of poisoning may occur suddenly without warning if cholinesterase levels are not allowed to return to normal. There are usually no serious long-term effects from small exposures, so long as renewed exposure is avoided until such time as cholinesterase levels return to normal. However, if exposure continues, there may be an irreversible inhibition of cholinesterase, resulting in long-term health effects.

Symptoms of poisoning include:

- Mild: loss of appetite, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis (excessive contraction of the pupil), impairment of visual acuity
- Moderate: nausea, salivation, abdominal cramps, vomiting, sweating, slow pulse, muscular tremors
- Severe: diarrhoea, pinpoint and non-reactive pupils, respiratory difficulty, pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma, and heart block

Carbamate Pesticides

This group of insecticides contains a range of toxic compounds from high to moderate toxicity. Examples of carbamate insecticides include: carbaryl, bendiocarb, and pirimicarb. The mode of action of these compounds is very similar to that of the organophosphorous compounds in that they inhibit the enzyme cholinesterase. (See “Cholinesterase Tests” at end of section). However, carbamates are broken down in the body rather rapidly and their effect on cholinesterase is quite brief. The reversal of the cholinesterase inhibition is so rapid that, unless special precautions are taken, measurements of blood cholinesterase of humans exposed to carbamates are likely to be inaccurate and always in the direction of appearing to be normal. The symptoms of carbamate poisoning are similar to those caused by the organophosphorous pesticides, but of shorter duration.

Botanical and Synthetic Botanical Insecticides

Botanical insecticides, as their name implies, are derived from plants. **Pyrethrum** is extracted from the flower heads of the chrysanthemum plant. It is a mixture of four compounds with similar chemical structure. **Resmethrin** is a synthetic pyrethroid with very similar characteristics to natural pyrethrum.

These compounds are **axonic**, meaning that they act by disrupting the electrical transmission of the nerve impulse down the axon. The **axon** is a long extension of the nerve cell body and is vital to the transmission of the nerve impulse. With the disruption of the transmission of the nerve impulse as it travels down the axon, the muscle system is rapidly paralysed.

Poisoning by this group is rare because of the low percent active ingredient in the products available and their relatively high LD_{50} values.

Symptoms of poisoning range from lack of coordination, tremors, salivation, and irritability to sound and touch, to the severe poisoning symptoms of nausea, vomiting, diarrhoea. They can produce allergic-type reactions from dermal exposure or irritate the throat and lungs (producing wheezing or coughing in some individuals) from inhalation.

The **pyrethroids** (synthetic analogues of pyrethrins) have a low to moderate acute toxicity to mammals and may be irritating to the skin.

Dithiocarbamate and Thiocarbamate Pesticides

This group includes fungicides and herbicides such as metiram etc. They are generally not very toxic. They do not inhibit cholinesterase. Some may be irritating to the skin, eyes, nose, throat or lungs. Very large doses may cause nausea, vomiting or muscle weakness.

Bipyridylium Herbicides

These are the most toxic herbicides that you may use. These pesticides (e.g., paraquat) may irritate the skin and mucous membranes including eyes, mouth, and lungs.

Symptoms of poisoning include:

- nausea
- vomiting
- diarrhoea, (often bloody)

Diquat causes profuse watery diarrhoea. Paraquat may cause difficulty in breathing.

Phenoxy Herbicides

These herbicides range from low to moderate in toxicity and include commonly used herbicides such as 2,4-D and MCPA. Exposure by breathing and absorption of the formulated products can produce ill effects particularly with some solvents used. Some are moderately irritating to the skin, eyes, respiratory tract and gut lining.

Symptoms of poisoning include:

- weakness, and perhaps lethargy
- anorexia, diarrhoea
- muscle weakness (may involve the muscles of chewing and swallowing)

Petroleum Products/Solvents

Petroleum products are used as solvents and carriers, or for their pesticidal properties (e.g., dormant oils). Two types should be considered:

Petroleum distillates (e.g., kerosene, solvent distillate, diesel oil): have a wide range of toxicities. Symptoms of acute poisoning may include nausea, vomiting, cough and irritation to the lungs, which may progress to bronchial pneumonia with fever and cough.

If more than 1 mg/kg has been ingested, symptoms of central nervous system depression and irritation may occur, including weakness, dizziness, slow and shallow respiration, unconsciousness and convulsions.

Chronic poisoning may cause weakness, weight loss, anemia, nervousness, pains in the limbs or peripheral numbness.

Aromatic hydrocarbons (e.g., xylene): have a wide range of toxicities. Symptoms of acute poisoning may include dizziness, euphoria, headache, nausea, vomiting, tightness in chest and staggering. More severe symptoms are blurred vision, rapid respiration, paralysis, unconsciousness and convulsions.

Cholinesterase Tests

The most acutely toxic insecticides used by applicators are in the organophosphate and carbamate groups. These products inhibit the activity of an enzyme known as acetyl cholinesterase or simply cholinesterase. Overexposure to these pesticides may lead to a significant decline in the activity of this enzyme and acute poisoning. It is important to understand the role of cholinesterase in the normal function of nerve cells.

When a nerve impulse travels from the brain to initiate the movement of a muscle, it must pass through a number of nerve junctions. At each junction, a chemical called acetylcholine is released to carry the nerve impulse across the gap between nerve cells. When acetylcholine reaches the next nerve cell, the impulse continues down the next nerve. The acetylcholine is then quickly destroyed by the enzyme cholinesterase. If it were not destroyed, repeated nerve impulses would be sent down the nerve. If cholinesterase is not working, the acetylcholine is not broken down and nerve impulses are repeatedly sent down the nerve. This results in a variety of poisoning symptoms ranging from headache, fatigue and dizziness in mild poisoning through nausea, trembling, convulsions, respiratory failure and death in severe poisoning.

A blood test is available to help medical personnel establish whether the symptoms are the result of poisoning by organophosphate or carbamate insecticides. When overexposure occurs, the cholinesterase level in the blood as well as that at nerve junctions is reduced in activity. Therefore, if a reduced level of cholinesterase in the blood is detected, it indicates poisoning from these insecticides.

However, there is no standard level of cholinesterase activity in human blood, and the variation from person to person in activity is very large. Therefore, individuals working with organophosphate or carbamate insecticides should have their base level cholinesterase activity in their blood measured before working with these pesticides. This base level is used for comparison to subsequent tests when poisoning is suspected.

In the absence of additional exposure, blood cholinesterase enzymes will regenerate in about 120 days from very low to base values in the case of organophosphorous poisoning, and more rapidly for carbamate insecticides. Cholinesterase testing must be done immediately following exposure to be of much value. The test is ineffective for the carbamate fungicides.

It is highly recommended that applicators working frequently with organophosphorous pesticides or carbamate insecticides monitor the severity of their exposure to these compounds through a cholinesterase test program. Contact your family physician for additional information.

Review Questions – Human Health

1. Applicators should have a cholinesterase test when working with

    a) organophosphates
    b) petroleum products
    c) chlorinated hydrocarbons
    d) all pesticides

2. What is cholinesterase?

3. When should cholinesterase tests be done?

4. What period of time is required for cholinesterase to return to the base level if poisoning has occurred?

CHAPTER 4 - PESTICIDE SAFETY

Section 1 - Aerial Application

Goals of this Section

When you have completed this section, you should be able to:

‘ describe major hazards associated with aerial application

‘ describe safe flying procedures for aerial application

‘ outline safe flagging procedures.

Introduction

Safety must be the number one concern of all participants in all stages of aerial application operations. Accident prevention is much more desirable than conducting clean-up operations and accident reviews after the fact. Training and education as well as commitment to professionally run, well-planned operations are essential elements of safe aerial applications.

While many laws and government standards have been established to promote safety, the ultimate responsibility for safe operations lies not with regulatory authorities, but with the individual. Pilots, loaders and field personnel must learn how to conduct their tasks safely and apply that knowledge to ensure the safety of themselves, others and the environment.

Every individual involved should have a checklist of "Do's and Don't's" for his/her specific job responsibilities, in compliance with regulations and company policy. Safe operating procedures should be reviewed on a regular basis with attention to applicability and effectiveness.

Hazards

As with any form of pesticide application, hazards are associated with aerial application. However, with aerial application, it is very important to remember that a lack of awareness of the following hazards can have dire consequences.

! Powerlines, trees and other high obstacles constitute the most common hazard associated with aerial application. In most accidents, the pilot was aware of the obstacle, but did not provide a sufficient safety margin to avoid contact.

- Inadvertent stalls and high speed stalls during pull-up or field entry constitute the second most commonly occurring factor in accidents.

- Fatigue and flying beyond the capabilities of the aircraft or the pilot can increase the potential for accidents.

By far the greatest concern in aerial application operations is the safety of the pilot and the aircraft during application work, including takeoff and landing. Several factors in recent years have contributed to a decline in accidents, but even with specialized equipment, this type of work still introduces hazards seldom encountered in other fields of aviation. These include:

- flying the aircraft at near gross weights at relatively low airspeeds
- operations at very low level, such that the risk of contact with obstructions is always a factor
- a high frequency of takeoffs and landings on a continuing basis, often from narrow, unimproved sites
- long working hours with frequent early morning operations and irregular sleep periods
- risk of exposure to toxic chemicals, which may affect the pilot's vision, increase drowsiness or interfere with balance or sense of direction

Causes of Accidents

Table 1 provides a summary of accidents and causes (prepared by the International Civil Aviation Organization, ICAO) for aerial application operations in the United States during 1979.

Pilot error is the cause of accidents in the majority of accidents involving aerial application operation. Errors of other personnel, such as loaders, mixers and flagmen, have been cited as causing accidents in a small number of cases. **Human error and careless or poorly managed operations are the major factors causing accidents.** Given the very high percentage of accidents associated with pilot error, it is evident that suitable pilot training, and on-the-job experience under supervision of expert pilots, are essential to a safe and professional career in aerial application.

A Safety First Attitude

There is no single element more important in ensuring safe operations than an attitude of "Safety First." This attitude must be taught, practised and supported by everyone. This is particularly important considering the long hours, remote locations and urgency to get the job done often encountered in aerial application projects. Strict adherence to safe operating procedures will permit safe, efficient and economic operations.

Before the operation, the project should be explained to all staff with attention to:

- objectives
- schedule
- daily routine
- hazards
- contingency plans in case of an accident
- reviewing the organizational chart

Table 1. U.S. Aerial Application Accidents, 1979 (ICAO)

Cause/Factor	Fatal Accidents		Non-fatal Accidents		Percentage of all accidents	
	Cause	Factor	Cause	Factor	Cause	Factor
Pilot	23	1	260	16	72	4
Other personnel	2	0	22	3	6	10
Airframe	0	0	0	1	0	0.3
Landing gear	0	0	12	1	3	0.3
Powerplant	0	0	75	5	19	1.3
Systems	0	0	2	0	0.5	0
Instruments/equipment and accessories	0	0	1	0	0.3	0
Airport/airways/facilities	0	0	2	16	0.5	4.1
Weather	0	1	2	38	0.5	9.8
Terrain	0	7	18	95	4.5	25.8
Miscellaneous/ Undetermined	3	0	17	4	5.1	1.0

Know Your Aircraft

An experienced pilot will spend sufficient time with an unfamiliar aircraft practising stalls at altitude until the knowledge of the symptoms of an approaching stall and stall recovery are both second nature.

For those just entering the profession, many hours of practice are needed to gain the “feel” of any aircraft, which becomes a significant part of the ability to handle it in the tight confines of aerial application work, most notably that encountered in agricultural operations. **Aerobatics (e.g., hammerhead turns, wingover turns and the like) have no place in aerial applications.**

Safe Application Procedures

Aerial application operations can be hazardous. It is essential that every consideration be given to reducing this hazard by providing the best possible equipment, the least tiring working conditions and reasonable limits on the length of the spraying sessions, with the greatest emphasis possible on accident prevention and reduction.

Safety Equipment

! Crash helmets should be considered the personal equipment of each pilot and crew member; these should be individually fitted for maximum comfort and provide high audio protection to prevent fatigue and hearing loss. This is particularly important for long operational times (for additional audio protection, ear plugs should be worn for high noise environment or during extended operations.) Helmets should be equipped with a bayonet-type mount to accept respirators suitable for the pesticide being used.

! Pilots and crew should wear comfortable, flame retardant flight suits and gloves. Nylon materials must be avoided wherever possible.

! In some situations such as forestry programs, it is essential to have radio communication between the mixing site and the aircraft.

Pre-Flight Requirements

Professional planning and common sense go a long way towards reducing the possibility of accidents. Know the following general safety items that are mandatory requirements in any aerial application operation.

! The pilot must be thoroughly trained in the appropriate aerial application procedures.

! All personnel must adhere to common sense personal habits regarding smoking, food, drink, sleep and hygiene.

! The landing/takeoff area must be carefully selected to provide safe operating conditions under all foreseeable conditions.

! A wind direction and speed indicator must be prominently visible in the landing area.

! The structural and operating limitations of the aircraft must be known and strictly adhered to.

! Personnel must maintain a high state of physical and mental alertness and avoid fatigue.

- The pilot must wear a correctly fitted, approved and well-maintained crash helmet.

- Toxicity, symptoms of poisoning and correct first aid procedures must be known by all personnel for the type of pesticide being used especially by those who may be exposed to the pesticide.

- The pilot must be well informed on current and forecast weather that would adversely affect flight safety or seriously affect application procedures.

Flying Procedures

The following safe flying procedures should be followed during training or operational work:

- Before the start of spraying, conduct an aerial inspection, circling the treatment area at a safe altitude and check carefully for obstructions. Check for:
  - breaks in crop patterns that may indicate hidden obstacles
  - guy wires on all poles and towers
  - wires leading into houses and other buildings
  - single insulators on the top of high transmission lines, indicating a single support wire often difficult to see
  - wires and poles obscured by trees or foliage; wires and poles are often located along roadsides and at ends of fields.

- Ensure flaggers are always upwind of the spray and well clear of the flight path.

- The pilot must maintain constant vigilance for hazards and obstacles on the ground and in flight.

- Fly successive swaths upwind to avoid exposure to airborne pesticide from previous runs.

- Racetrack "P" patterns minimize fatigue and manoeuvring required when compared to shuttle patterns and allow more time for alignment for the next run.

- With shuttle patterns, turn downwind before swinging into the upwind portion of the turn to expedite and provide better aircraft positioning for the subsequent procedure turn onto the next swath.

- Do not look back during application runs. Select alignment cues during the turnaround.

- Fly ground contours wherever possible, avoiding upslope flying that could cause rapid airspeed decay and possible stalls.

- If possible, carry out a ground inspection or receive an obstacle briefing from flaggers of the area to be overflown.

- Ensure that if a GPS is used, coordinates are logged in ahead of the flight and not during the flight.

- Fatigue is one of the most common physiological problems for pilots. Fatigue degrades performance so that the pilot cannot carry out tasks as reliably and accurately as he/she should.

Pilots must receive training on aircraft handling appropriate to the type of aircraft and application operations.

To avoid stall/spin situations:

- do not overload the aircraft
- avoid sudden pull-ups and tight turns
- whenever possible, do not turn during the pull-up at the end of a run
- keep roll rates to a minimum when commencing and completing turns
- delay short runs and “touch ups” for when the aircraft has a light load.

Pilots of rotary-wing aircraft should pay particular attention to information contained in the pilot’s manual on the following points:

- using torque to help in turns
- vortex ring state (settling with power)
- mast bumping
- loss of tail rotor authority (unanticipated right yaw).

Meteorology

Of the many critical factors contributing to safe and effective aerial applications, some of the least understood lie in the area of meteorology. These factors will be covered in later sections with respect to their influence on droplet size and behaviour as well as drift management.

In addition, the applicator must be knowledgeable about other meteorological factors such as density altitude and low-level wind shear that affect the performance of the aircraft.

It is apparent that the applicator must deal with these many variables and try to limit application to those times when all these factors are, if not optimum, at least within workable parameters. In situations where time is short, there may be a strong urge to work in situations that may compromise either effective application or flight safety. This must be avoided.

Awareness of current and forecast weather conditions is required for safe and effective aerial application.

Specifically, the pilot should be aware of:

- frontal movements that would affect application
- wind speed and direction, particularly when sensitive areas are nearby
- gusts, squalls or low-level turbulence that could compromise safe flight with a heavily loaded aircraft
- times of sunrise, sunset. These should be used in conjunction with local weather to determine the times when sufficient light exists to commence or continue operations
- rain and thunderstorm warnings
- cloud type, base, height and amount
- density altitude
- wind shear.

Flagging Safety

The following safety considerations should be covered for all flagging personnel and the pilot:

- A complete briefing between pilot and flaggers is essential for safe operations. This should cover proper positioning, when to move upwind, radio communications and ground signals where no two-way radio exists.

- Depending on the circumstances, the flaggers should have access to meteorological equipment such as an anemometer to measure wind speed and a sling psychrometer to measure temperature and relative humidity. This equipment can provide spray site information enabling the pilot to make appropriate decisions regarding application.

- New flaggers should be trained on proper flagging procedures and paired with experienced personnel for orientation to company procedures and skills training.

- The flagger should keep the aircraft in sight at all times. They should never turn their back on an approaching aircraft.

- Start on the downwind side of the field, working into the wind to avoid exposure to the pesticide because of drift. Under no circumstances should flagging continue if there is any danger of serious contamination of personnel because of wind shifts or other atmospheric changes.

- Move to the next upwind position as soon as the aircraft is lined up for the current run. The most common error with inexperienced flaggers is that they do not move soon enough. Once the aircraft is properly aligned, there is no necessity for the flagger to maintain position. As a rule of thumb, the flagger should be in the next upwind position and be turned to watch the aircraft a minimum of 5 seconds before it passes by the flagger on the previous run.

- Flaggers should be knowledgeable about the toxicity of the pesticide in use, its effects upon humans and proper first aid procedures if poisoning is suspected.

- Be alert for guy wires and other obstacles. Avoid flagging near them and inform the pilot of their presence.

- Flaggers should be well trained on procedures to follow in the case of an aircraft accident.

- Wear protective clothing including goggles, gloves and a respirator that are appropriate for the pesticide and highly visible from the air. Light coloured, liquid proof overalls with a hood/head protection over long pants and long shirt provide good protection and good visibility.

- The safety of the flaggers is one of the most important responsibilities of the pilot. He must ensure they are not in jeopardy either from being struck by the aircraft or contaminated by spray.

- Radio communication, while not essential for some smaller operations, is a must in forestry or programs dealing with large blocks or ferrying distance.

- Whenever possible human flaggers should be replaced by mechanical flaggers or should be in an enclosed vehicle.

Review Questions - Aerial Application

Hazards

1. In most accidents involving high obstacles such as powerlines, the pilot was aware of the obstacle but failed to provide a sufficient safety margin.

   True False

2. Inadvertent stalls during pull-up can be reduced by knowing the capability of the aircraft.

   True False

3. List 5 factors that contribute to the hazard of aerial application for the pilot.

Safe Application Procedures

1. Pilots should fly successive swaths downwind to be able to check coverage.

   True False

2. With shuttle application patterns, tight turns keep the pilot alert.

   True False

3. Avoid upslope flying that could cause rapid airspeed decay.

   True False

4. It is always good procedure to circle the treatment area at a safe altitude and to check for obstacles.

   True False

5. Stalls in the procedure turn are causes of accidents.

   True False

6. Whenever possible, turn during the pull-up at the end of the run.

   True False

Meteorology

1. Name 2 meteorological factors that are important to aircraft performance, particularly for aerial application.

Flagging Safety

1. Flaggers should start on the downwind side of the field and work into the wind.

   True False

2. Flaggers should flag near guy wires to keep the pilot aware of the presence of this obstruction.

   True False

3. Flaggers should be knowledgeable about the toxicity of the materials being sprayed, know the poison symptoms and know the first aid procedure.

   True False

4. The pilot and the flaggers must work as a synchronized team and be on the lookout for everyone's safety.

   True False

5. Describe safe flagging procedures, including the following topics:
   - training
   - visual contact with the aircraft.

Section 2 - Pesticide Storage, Mixing and Loading

Goals of this Section

When you have completed this section you should be able to:

- describe requirements for the mixing/loading site, temporary pesticide storage and the airstrip
- outline appropriate equipment and safety procedures for mixing and loading operations using liquid and dry material systems

Introduction

The handling, mixing and loading of materials are a vital part of aerial application operations. The pilot is generally responsible for verifying that proper types and amounts of pesticides are being applied.

Three main considerations for mixing and loading operations include:

- a carefully selected, well organized mixing and loading site
- a mixing and loading system to ensure safe, efficient pesticide mixing and/or loading into the aircraft
- a well-trained ground crew

Site Selection and Organization

A carefully selected organized loading site will ensure the aircraft spends the minimum time on the ground and the maximum time spraying.

- The site should be adjacent to the airstrip and as close as possible to the area being sprayed and a water source. Long ferrying distances can substantially increase the time required to complete a program

- The ground surface should be suitable for heavy vehicle operation.

- The mixing and loading site should be inaccessible to the general public.

- The layout will vary, but fuel and pesticide must be kept well apart with suitable storage facilities for each.

! A paved area or cement pad for washing and loading is desirable, but not always practical. Figure 1 shows an example of a permanent loading site. Figure 2 illustrates a typical mobile mix rig.

Forest operations often use aircraft spraying in formation and thus require a set-up that permits simultaneous loading of two or more aircraft. Figure 3 shows a typical forestry "tank farm".

Figure 1. Permanent Loading Site

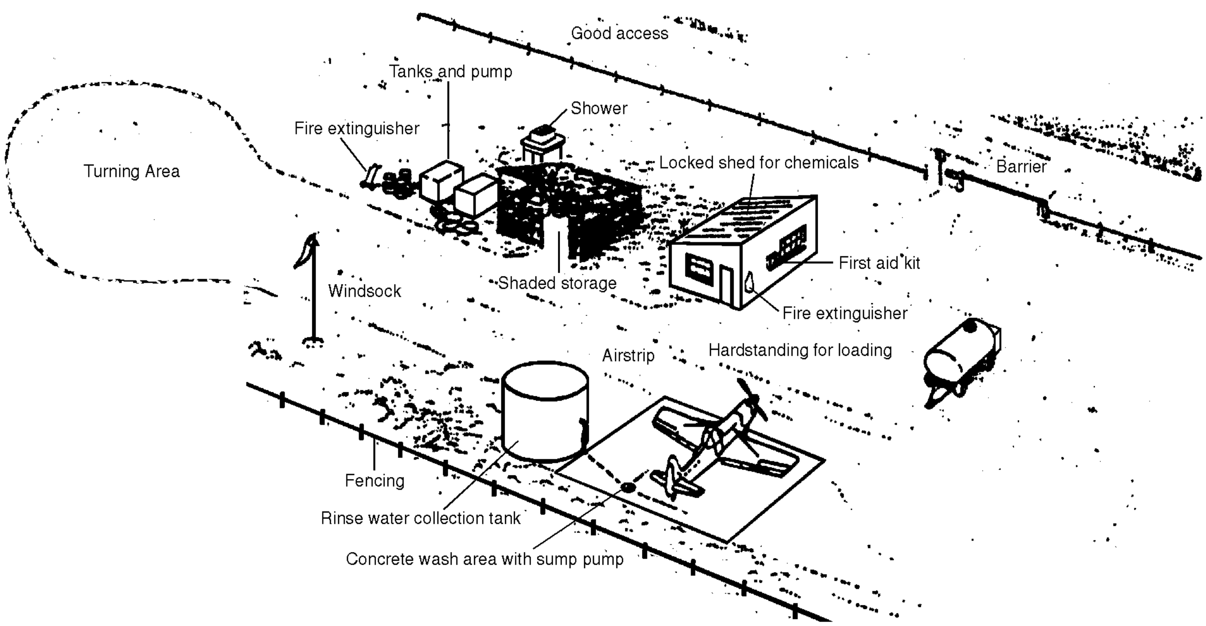
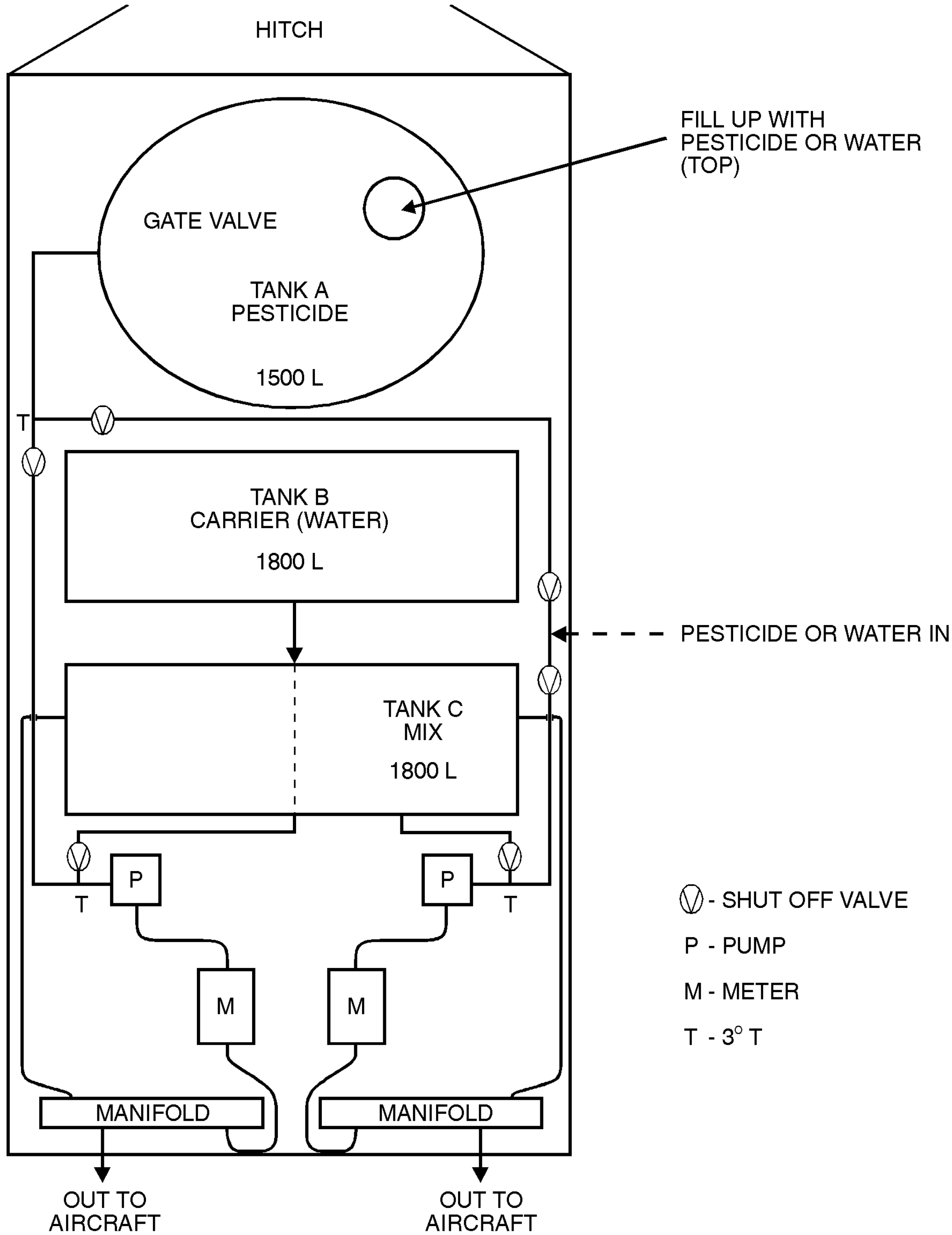
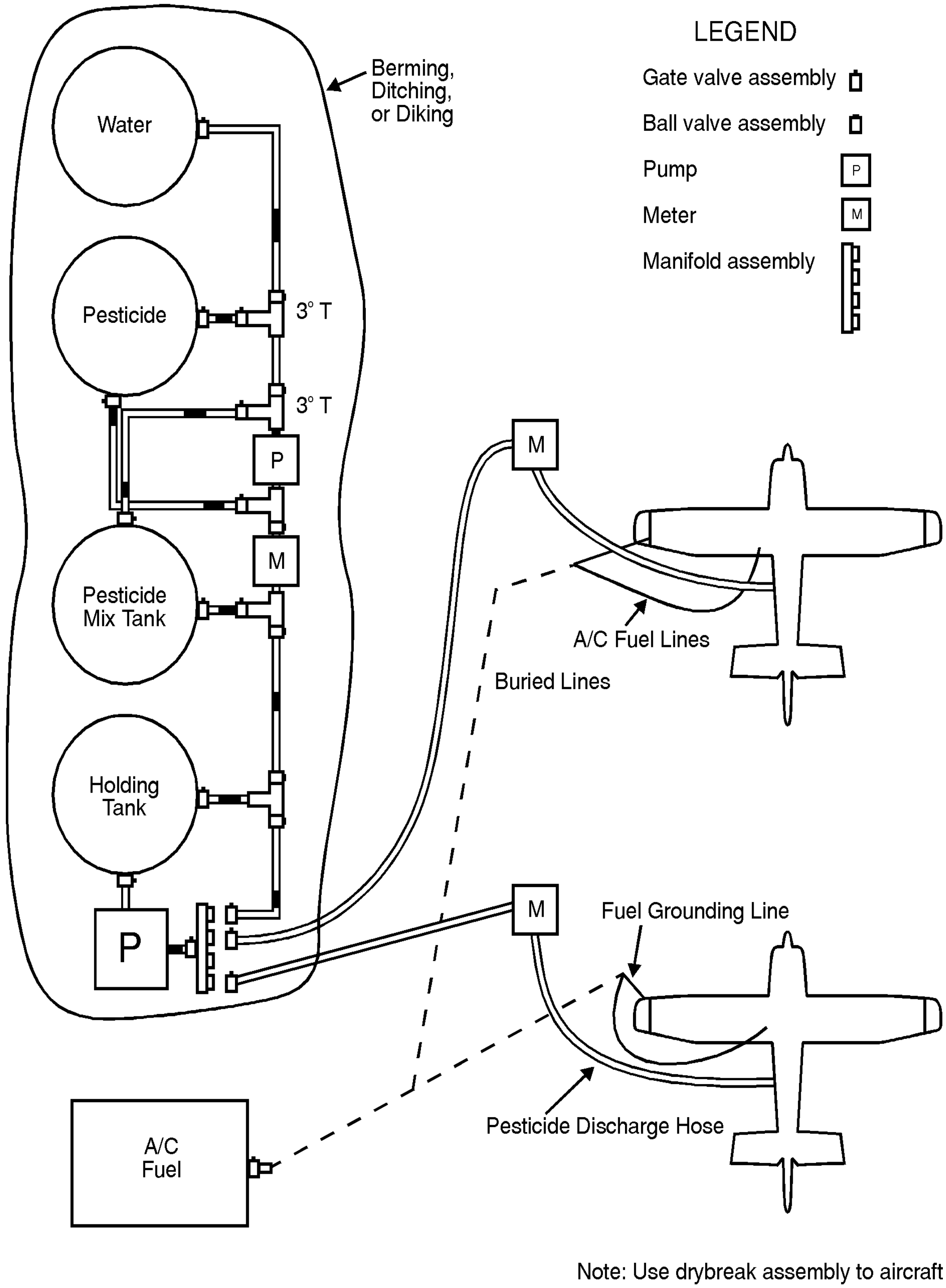


Figure 2. Diagram of a Mobile Mixing/Loading Rig



Depending on the mix ratio of carrier to pesticide, storage tanks A and B may change roles from pesticide to carrier storage. For a herbicide mix, the larger tank would logically be used for water, the smaller for herbicide.

Figure 3. 'Tank farm' Set-Up for Forestry Operations



Guidelines for Temporary Pesticide Storage

Some aerial application projects require a temporary pesticide storage location. Many of the principles that apply to permanent storage apply to temporary storage. Temporary outdoor pesticide storage areas must meet the following requirements:

- Temporary storage areas must be located on ground that is flat and not highly permeable and away from a watercourse such as a lake, stream or river. The distance will depend on the soil type, slope and topographical situation of the area.

  The floor must be constructed to contain spills. It may be desirable to dig a ditch around the storage area to contain any spills and prevent contamination of the surroundings.

- A pesticide transport vehicle or portable trailer may be used as a temporary storage area. If portable trailers are used, you may rely on a makeshift ventilation system, provided all containers are tightly sealed. Alternately, a vent to the outside with an exhaust fan may be appropriate. The trailer must be locked to prevent entry by unauthorized people.

  If no trailer is available, containers must be securely fenced off using snow fencing or a tarpaulin. Sufficient security measures must be taken so that only authorized persons have access to the pesticides.

- A placard must be posted at each entrance bearing the words:

  Chemical Storage, WARNING, Authorized Persons Only.

- Guard against deterioration of pesticide containers by using pallets, appropriate ground sheets or a tarpaulin, if the type of container warrants it.

- Make protective clothing and safety equipment readily available in an area separate from, but close to the pesticide storage area. There must be enough clothing and equipment to protect a person from the adverse effects of the pesticides stored and handled in the area.

- Make sure that there is enough absorbent material, decontaminants and spill emergency equipment nearby for cleaning up spills or leaks from containers.

- A communications system is recommended for contacting help in an emergency.

- Emergency response information must be readily available.

Regardless of the type of set-up, fire extinguishers and first aid kits should be available at the mixing site. Also a large supply of clean water (minimum 200 litres) for a deluge shower and soap as well as an eyewash station (if appropriate for the type of pesticide being used) must be located at the mixing sites to wash up in the event of accidental chemical spill.

Airstrip Requirements

The condition of the airstrip is an important consideration for the safe handling of pesticides as well as the safety of the entire operation. Ensure that the airstrip is graded and packed. The applicator should inspect and approve the airstrip at least two (2) weeks before the project starts. The airstrip must be acceptable to the pilot.

The loading/mixing site can be at either end of a flat airstrip, but only at the high end of a sloping airstrip. It should be at least 25 metres in diameter with a further 10 metre wing clearance around the perimeter. If two or more planes are using the same facilities, the turn-around should be 40 metres in diameter, also with a 10-metre wing clearance. The turn-around can be constructed as a widening of the road surface.

The loading/mixing equipment should be located alongside the turn-around preferably on the left-hand side so that the plane will be in taxi position before loading. All hookups are located along the left-hand side of the fuselage.

Helicopters can virtually land and take-off anywhere provided there is safe/adequate rotor clearance. However, the mixing/loading area must be well organized and not congested.

Careful attention to site selection and organization will ensure an operations base that is safe with respect to general working conditions, fire hazards and living conditions if required.

The Mixing and Loading System

Safe, efficient mixing and loading operations require:

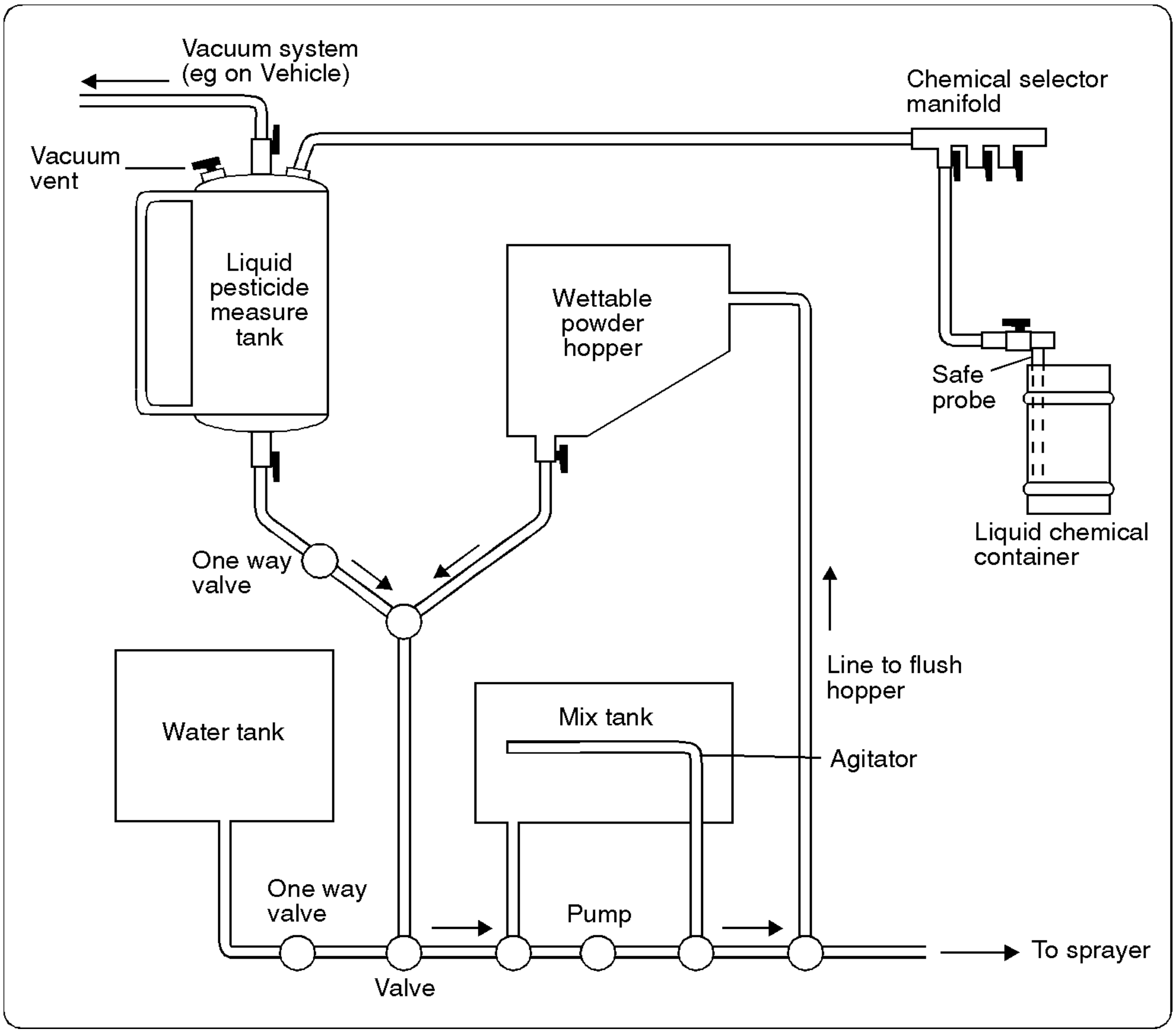
- a carefully selected, well organized mixing and loading site
- a mixing/loading equipment system to ensure safe, efficient pesticide mixing and/or loading into the aircraft
- a well-trained ground crew

The ground support equipment must provide safe handling and mixing of dry or liquid materials. The equipment must provide for rapid loading and be suitable to prepare load sizes consistent with the capacity of the aircraft. The appropriate hoses, fittings, flow meters, and filters must be in good shape with replacements available should they be required. For mobile operations, the ground support equipment must be easily transportable.

Liquid Mixing and Loading Equipment

Liquid materials require special equipment for field mixing and handling. Most systems are custom designed by individual operators to suit their specific needs. However, all have the general design features shown in Figure 4.

Figure 4. Schematics for Liquid Loading System



Safe mixing and loading is a key factor in the design of ground support units, particularly when highly toxic materials are used. The design of the system should take into account the following operational considerations:

- All storage tanks should be accurately calibrated.

- The clean water storage tank should be loaded through a filter to remove any impurities that could clog nozzles or adversely affect the pesticide action. One way check valves should be installed to prevent any backflow from the mixing tank and contamination of the fresh water supply or of the pesticide tank.

- Large transportable water tanks should have interior baffles to prevent instability from sloshing during transportation. The tanks should be durable and made of non-rust material such as fibreglass, aluminium, stainless steel or industrial plastic. Tanks vary in capacity from 1000 litres to upwards of 10,000 litres.

- The mix tank's capacity does not need to be that of a full aircraft hopper/tank load, but must be of sufficient size to permit the full dose of pesticide to be mixed with an adequate supply of diluent. Mixing tanks are usually 100 to 1000 litres capacity. They must be made of chemically resistant material and should contain some type of agitator to ensure adequate mixing of the load.

- A truck equipped with a high box and hydraulic tailgate or a Hiab loader and a barrel sling is needed for transport and safe handling of drums of pesticides, solvents, etc.

- A clearly legible chart should be prepared showing amounts of various spray ingredients to be used in standard batches of tank mix and show corresponding amounts for double batches and half batches. Lettering should be waterproof and legible. Post chart at the mixing site.

- All tanks and drums should be vented to prevent collapse when material is removed. Vent pipes should have the opening facing down to prevent rainwater from entering the tanks.

- Meters to measure the amounts transferred must be accurately calibrated with the mix being used and monitored for accuracy since readings will change with different fluid viscosity.

- Whenever possible, dry-break type valves should be used for aircraft loading. These should prevent any loss of chemical or dripping during connect and disconnect operations.

- The system must include high output pumps (centrifugal) that are suitable for the transfer of the pesticide to the mixing tank, agitation and loading the mixture into the aircraft.

- Depending on the operation, the pesticide may be taken directly from the manufacturer's container or from a holding tank to the mixing tank or directly to the aircraft if the pesticide is not diluted.

  When a holding tank is used, tank composition must not react with the concentrated pesticide and must be suitably designed to prevent collapse or rupture from the weight of its contents when full. Also precautions should be taken to avoid the inadvertent puncture of the tank.

  A manual or electric barrel pump is recommended for drawing liquid material from drums. Alternatively, a valve installed in the bung of a horizontal drum can be used to control flow. This is available commercially as a "molasses valve" (Rieke Valve), or it can be made. If the loading system is equipped with 5-cm quick couplets, a male coupler may be threaded into the drum.

- The tanks, hoses (5 cm), filters and couplings (quick couplers) should be secure and large enough to easily accommodate the pumping system and appropriate to the pesticide and mixtures being used. Materials should be (clean, leak-proof and chemical resistant; **fire hose is not adequate**.)

- The system should include site gauges that are protected from damage and easily visible.

- A second by-pass line and in-line filter will allow loading to continue if the primary filter becomes blocked.

- Valves and controls should be easily accessible and clearly marked.

- The mixing and loading system should also include a separate rinsing system to facilitate the rinsing of empty pesticide containers in a safe and efficient manner.

- A large bucket of clean water should be kept nearby to immerse the end of the loading hose and keep it clean.

- Wherever possible, decals that describe operating procedures should be fixed to each component and maintained in a readable condition.

- The pesticide label should be attached and maintained in a readable condition on all containers used for pesticide storage.

The crew must implement a regular maintenance schedule with ongoing records of inspection and repairs of the mixing and loading equipment. Also, to ensure the effectiveness of the pesticides, safe handling, as well as maintaining equipment in working condition, pesticides should be mixed just before use and not left in mixing tanks for extended periods of time.

Whenever possible, the mixing/loading operation should be designed as a **closed system**. The pesticide should be removed from it containers, the containers rinsed and the mix transferred to the aircraft without directly exposing individuals to the pesticide concentrate or to the mixture.

Because pesticide containers and holding tanks generally are not designed to be pressurized, closed systems remove the material by gravity or a suction system. Some systems require the placement of the pesticide container in a steel box where the container is opened and the contents are either drained or pumped out to the mix tank or aircraft hopper. Others involve the insertion of a stand pipe or suction probe directly into the pesticide container.

Remember that large holding containers when partially full of pesticide can be subject to condensation. The quantity of water formed by condensation can dilute or significantly affect the physical properties of the pesticide. Try to minimize condensation by reducing the size of the container or by keeping the holding tanks almost full, leaving some space to allow for product expansion during periods of high temperatures.

Regardless of the type of mixing/loading system used, it is important that all personnel wear proper protection and use safe handling procedures at all times.

Dry Materials Loading Equipment

Some granular materials are supplied in the dry formulation and do not require field mixing facilities. They are added directly to the aircraft hopper manually from manufacturers' containers or by manually operated equipment such as overhead hoppers, an elevator conveyer belt or an auger.

The most common form of dry loader is a mobile crane assembly with a basket large enough to load the aircraft hopper in a single operation.

- The dry material loaders should be of sturdy, reliable construction and easily mobile allowing maximum visibility to the operator during movement and loading.

- The loading equipment should also have a volume or weight measuring capability to ensure accuracy of loads.

Mixing and Loading Responsibilities

The certified applicator is responsible for ensuring that the pesticide mixers/loaders are trained or certified in those tasks necessary to safely do their job.

Each member of the crew must understand his/her responsibilities and be aware of the responsibilities of the other crew members. This information, and knowing to whom they report to, will enable the members of the crew to function as a safe and efficient team.

The pilot must ensure that products used meet label requirements for aerial application. The pilot or crew supervisor must ensure that proper mixing instructions are available and followed. For example, most pesticides should be mixed just before use and not left in mixing tanks for extended periods of time since they may degrade.

Some provinces prohibit pilots from mixing and loading. Refer to provincial legislation regarding pilot involvement in mixing and loading.

The crew must follow the mixing procedures provided on the label, load the aircraft to its proper capacity and have sufficient load ready for the next turnaround. Rapid mixing and handling facilities are highly desirable, since they significantly reduce aircraft downtime and increase application times.

Occasionally problems occur that may be related to the potency of the product or performance of the tank mix. At the very least, the crew supervisor should note the batch number, expiry date or other relevant information on the pesticide container. If possible, keep a labelled sample of the product and/or mix available if problems arise with the product so that analysis can be made on the product. Contact the supplier regarding the sample size appropriate for analysis. **Remember that the sample will have to be disposed of in an environmentally sound manner.**

Mixing and Loading Safety Precautions

Mixing/loading operations potentially expose personnel to the most direct contact with the pesticide being used. Consequently, safe operating procedures are mandatory. Personnel should observe the following guidelines.

General

- Be certain to read the label of every pesticide used. Labels are carefully prepared and carry the necessary information about rates, uses, cautions and hazards.

- If a label is damaged or illegible, do not use the material until you are sure of the chemical being used. In addition to the label, operational personnel should be familiar with the Material Safety Data Sheet and the product's toxicological profile.

- Wear clean and well-fitted goggles or a face-shield (or a respirator if required), chemical resistant gloves, coveralls over 1 layer of clothing, rubber boots and an apron for protection in the event of a splash or spill. This is especially important when handling highly toxic materials. Wear any additional PPE required on the pesticide label.

- Change clothes daily and more often if any contamination occurs. Shower thoroughly, with special attention to hair and fingernails at the end of the day.

- Discard leaky gloves or contaminated boots.

- Make sure that there is a wash-up area with plenty of soap and water, eyewash and a medical kit nearby.

- Wash skin surfaces and clothing in soap and water immediately if any contamination occurs.

- Learn to recognize the typical signs and symptoms of pesticide poisoning.

- If you feel ill at any time, seek medical attention at once. Do not carry on because of the work schedule.

- Have a good supply of lime, sand or other non-combustible absorbent to soak up a spilled pesticide.

- Never use your mouth to siphon liquid material or to blow out clogged spray nozzles.

Before Loading

- Before preparing a spray mixture, study the label on the container, calculate the quantities required and plan how to conduct the mixing and loading safely.
- Ensure weather conditions are still suitable for application.
- Check that the correct quantity of product has been mixed and follow the safety directions.
- Ensure all hoses, fittings and clamps are sound and secure.
- Check that loading nozzles and filters are clean and serviceable.
- Ensure the pump is operating efficiently and that inlet and outlet hoses are connected properly.
- Ensure drums and containers are sealed before moving them into position.
- Ensure that the spray system is clean and void of non-compatible materials.

During Loading

- Pilots should not perform mixing/loading of pesticides. Refer to provincial legislation regarding pilot involvement in mixing and loading.
- Do not eat, drink or smoke during loading operations. (Confine smoking to specific areas.)
- Open all pesticide containers carefully and on a stable surface where they won’t tip or spill.
- Open, pour and mix in a well-ventilated area where the possibility of contamination is minimized, and where any spills can be properly cleaned up.
- Use the appropriate tools to open containers (i.e., use a knife to open paper and plastic bags).
- Be careful when opening containers that have been standing in the hot sun, since there can be considerable pressure because of heating.
- Stand upwind of all opening, pouring and mixing operations.
- Avoid splashing and spurting by holding the container so the opening is at the top. If an air vent is provided, use it.
- Approach the aircraft only when the pilot signals that it is safe to do so.

- If filling directly into the aircraft hopper or tank, stand with your head well above the opening.

- Take care when connecting or disconnecting the loading hose from the aircraft.

- When adding pesticide concentrate directly to the aircraft, add it when the hopper is at least half full with diluent. Open the containers carefully to avoid spillage of liquid or dispersion of powders. Add the pesticide by keeping the container as close as possible to the surface of the diluent, allowing the concentrate to slide into the mix. While doing this, the loader should stand with his back to the wind.

- If the loader is assisted in the loading operation, care should be exercised if transferring pesticide containers from one person to another.

- Empty pesticide containers must be thoroughly cleaned using the triple rinse method. A drum rinser using 2.5 cm PVC pipe can be made to rinse containers. Cap the end and make a series of horizontal cuts around the bottom 75-cm of the pipe. This attached to a small pump system and water supply will do the job. Add rinsate to the spray tank, otherwise disposal must be according to provincial requirements and can be a major problem.

- Wash the probe and any accidental spillage on the ground or the sides and tops of pesticide containers. Add rinsate to the next load in the spray tank, if the spray materials are the same. Otherwise, dispose of the rinsate according to provincial guidelines.

After Loading

- Tanks and hoppers should be tightly sealed. If the lids do not shut tightly, use tape or silicon seal to keep lids secure and to prevent spillage. The pilot should be informed when a new gasket is required.

- Clean off any chemical remaining around the top of a hopper or tank immediately.

- Ensure the loading valve remains clean.

- Keep all equipment properly cleaned and stowed away when not in use.

- Securely store pesticides and loading equipment when operations are temporarily discontinued.

After the Spray Session is Completed

- At the end of the spray session, clean all remaining pesticide containers of any spillage or dirt that could damage the label.

- Puncture and remove all empty, rinsed containers to a proper disposal location, preferably a pesticide container recycling centre if available.

! Thoroughly clean all equipment and wash down the loading area.

! At the conclusion of the spray program remove in-line screens, nozzle screens, diaphragms and nozzles and clean them in a detergent water solution.

! Flush the aircraft spray system in the appropriate manner.

! Remove and store unused pesticides.

Review Questions - Pesticide Storage, Mixing and Loading

Site Selection and Organization

1. Both fuel and pesticides are considered hazardous and can be stored together in the same area.

   True False

2. List considerations for the location of a temporary pesticide storage facility.

The Mixing and Loading System

1. Contamination between the mixing tank and the pesticide or fresh water tank must be avoided through the use of one way check valves.

   True False

2. Vent pipes are essential for all holding tanks to prevent their collapse when material is removed.

   True False

3. Dry-break valves should be used for aircraft loading.

   True False

4. All pesticide containers including bulk holding tanks should have a pesticide label.

   True False

5. Ideally, mixing/loading operations should be designed as an “open system” to allow better control over the mixing process.

   True False

6. Holding tanks with pesticides should be kept as full as possible especially with outside storage over a long period of time to prevent contamination from water because of condensation.

   True False

Mixing and Loading Responsibilities and Precautions

1. The pilot is responsible for ensuring that the ground personnel load the pesticide into the aircraft correctly and should be prepared to participate in the loading process if properly clothed and equipped.

   True False

2. The pilot as the applicator must ensure that products are registered and classified for aerial application before the application.

   True False

3. Each crew member is responsible for his/her own safety.

   True False

4. If mixing the pesticide with a diluent in the aircraft hopper, the pesticide would be loaded first followed by the diluent.

   True False

5. Rinsate from empty containers should be compatible with the spray mixture in order to add the rinsate to a load for disposal by spraying.

   True False

6. A person filling directly into the aircraft tank, should keep their head below the opening.

   True False

7. List 4 general safety precautions regarding protective clothing/gear to prevent a worker from being exposed to a pesticide when mixing.

CHAPTER 5 - ENVIRONMENT

Goals of this Chapter

When you have completed this chapter, you should know:

‘ the potential environmental impacts by aerial application:

  < of pesticides to agricultural land
  < of pesticides in forest management
  < of herbicides for industrial vegetation management
  < for biting fly control

‘ guidelines for preventing exposure to bystanders and the harmful environmental effects from:

  < aerial application in agriculture
  < aerial application in forestry and industrial vegetation management
  < aerial application for biting fly control

Introduction

Aerial applicators should have a basic understanding of the potential impact of pesticides on the environment and ways to protect both land and water, and they need to be aware of requirements for buffer zones.

Agriculture

Impacts

Potential environmental impacts from aerial applications in agriculture include the following:

! exposure of workers or bystanders to pesticides
! contamination of domestic water supplies
! contamination of crops (particularly organically grown crops) or cropland devoted to organically grown crops, adjacent to treated area
! damage to nearby non-target crops
! poisoning of honey bees and other pollinating insects

- contamination of natural waterbodies and aquatic organisms that may be a food source for fish or wildlife
- elimination of beneficial insects that hold pest insects in check.

Guidelines for Environmental and Bystander Protection

- Do not spray fields occupied by farm workers or bystanders. It may be necessary to post warning signs prior to spraying to keep people out during the pesticide applications. Check with provincial regulatory authorities.

- Apply pesticides at a time of day when bystanders are least likely to be near (i.e., do not spray areas near public roadways when school children are present, particularly between the hours of 7:30 to 9:00 a.m. and 2:30 to 4:30 p.m.).

- Leave adequate buffer zones between spray operations and sensitive areas such as public roadways and adjacent private properties to prevent injury to, or contamination of, animals and vegetation.

- Leave adequate buffer zones around treatment areas to ensure there is no contamination of adjacent lands, farmlands or land devoted to organically grown crops.

- Leave appropriate buffer zones from bodies of water so that domestic water supplies and sensitive aquatic habitats such as sloughs, ponds, coulees, prairie potholes, lakes, rivers, streams and wetlands are not contaminated.

- Employ a ground field observer in communication with the pilot to monitor weather parameters and drift where there is a potential hazard.

- Minimize pesticide spray on fence rows and field edges, which are often habitats of animals and beneficial insects.

- Beekeepers in or adjacent to proposed treatment areas should be notified since insecticide use may pose a hazard to their colonies.

Forestry and Industrial Vegetation

Impacts

Potential impacts of pesticides on the environment in forestry and in industrial vegetation control are a special concern because very large areas may be treated, which provide habitat for a diverse number of plants and animals.

Herbicide application for site preparation, brushing and conifer release or industrial vegetation control is associated with the following concerns:

- potential for contamination of waterbodies and indirect effects on aquatic animals by sublethal effects or alteration of planktonic food supplies
- loss of vegetation canopy over streams, which protects against temperature extremes and erosion, and contains insects and plants important to the stream ecosystem
- loss of cover for birds, ungulates, carnivores and their prey
- loss of forage vegetation, particularly for ungulates, and
- loss of diversity of plant species, which encourages pest species and is ecologically unstable.

Use of some insecticides in forestry, particularly organophosphates and carbamates, may have a direct toxic effect on songbirds. These insecticides may also have an effect by altering bird behavior. Insecticides applied over large areas may have an impact by removing insects important as food sources and as pollinators. Beekeepers in or adjacent to proposed treatment areas should be notified since insecticide use may pose a hazard to their colonies. There is a concern for contamination of domestic water supplies and waters that harbor fish and other aquatic animals.

Guidelines for Environmental and Bystander Protection

- Employ appropriate pre-notification procedures (as specified by provincial regulatory authorities) to inform the public of the planned spray program.

- Maintain a contact person at a publicized telephone number to receive questions and provide information on the spray program.

- The pilot should conduct a thorough pre-treatment aerial inspection of the treatment site to ensure the pilot’s familiarity with the treatment area.

- Mark environmentally sensitive areas on aerial photographs for reference during application.

- Entry to treatment areas must be prevented during application. Access roads should be blocked and placarded to warn bystanders of application.

- Avoid spraying when wild berries are ripening if there is any potential for contaminating berries for human consumption.

- Prevent contamination of water used for domestic purposes.

- Maintain a suitable buffer zone to prevent spray drift into environmentally sensitive areas such as sensitive aquatic habitats and streamside vegetation, as identified by local fish and wildlife officials (or a specific buffer zone width may be required by provincial regulatory authorities).

- Survey treatment areas near watercourses or waterbodies and ensure the boundaries are clearly defined or marked.

- Where flagging is used, such as balloons or plastic markers, they should be located along the boundary of the treatment area, not the area to be protected.

- Begin the first spray swath wherever possible along the edge of the treatment area that borders a stream or river buffer; subsequent swaths can be perpendicular.

- If a treatment area is bounded on two sides by sensitive areas, make certain the treatment block is large enough for aerial application with the appropriate buffer zones.

- An experienced ground crew should be present to monitor drift and to inform the pilot of changing conditions or excessive drift.

- When using herbicides in areas important for wildlife browse, options include leaving areas in a large block to be treated in following years or selective application in some areas by ground only.

Biting Fly Control

Impacts

Sloughs, ponds, marshes and other still-water areas that breed mosquitoes can support rich and diverse fish and wildlife populations. Mosquito larvae can be a food source for insects, fish and other animals. In larvicide programs, areas of high fish and wildlife value should be identified and given protection. Areas which are usually protected from pesticide treatment for mosquito larvae include:

- back channels of streams and rivers, which are often fish rearing areas
- weedy shorelines of lakes, which are essential areas for waterfowl
- drainage ditches connected to fish-bearing waters.

A major concern for applicators is the potential of pesticides drifting onto these protected areas and into other non-target waters. Appropriate buffer zones should be used to protect sensitive and non-target areas.

Adulticiding over residential areas raises concerns about the potential hazard to health for exposed individuals.

Guidelines for Environmental and Bystander Protection

- A larviciding program is generally preferable to adulticiding for effectiveness and to reduce widespread pesticide dispersal in the environment.

- Do not apply pesticides to waters used for domestic purposes.

- Do not apply pesticides to fish habitat identified as non-target areas by local fisheries authorities and take care to prevent their contamination from drift.

- Both larvicides and adulticides should only be applied by air where it is not reasonable to apply with ground-based equipment to minimize drift.

- Before aerial applications, provide adequate public notice so that affected residents will be aware of the program and take any necessary protective measures for the pesticide spray program.

- Employ appropriate pre-notification procedures (as specified by provincial regulatory authorities) to inform the public of the planned spray program.

- Maintain a contact person at a publicized telephone number to receive questions and provide information on the spray program.

- Do not conduct aerial applications when residents and bystanders are unprotected and exposed to the spray.

- If necessary, advise residents with home gardens to wash produce or leave product unharvested for specified time periods.

- Beekeepers in or adjacent to proposed treatment areas should be notified; insecticide use may pose a hazard to their colonies.

Review Questions - Environment

1. It is not necessary to post warning signs to keep people out of a crop treatment area as long as the owner of the field has been notified.

   True   False

2. The protection of bystanders is of minimal concern when applying herbicides in a forestry situation because herbicides kill unwanted vegetation not people.

   True   False

3. The application of herbicides for conifer release adjacent to running water can impact on fish species requiring cool water.

   True   False

4. Where flagging is used, markers should be placed along the perimeter of the non-target area to remind the aerial applicator not to spray this area.

   True   False

5. In some situations involving industrial vegetation management in a wilderness area, aerial application can be inappropriate.

   True   False

6. Although mosquito larvae tend to be the most obvious organisms in standing water, other organisms co-habit these areas and should be considered before application of an insecticide.

   True   False

7. Mosquito larviciding is usually more effective and environmentally acceptable than adulticiding.

   True   False

8. List 4 possible environmental impacts from aerial application of pesticides to agricultural land.

9. List 4 potential harmful effects of aerial application of herbicides to forests, woodlands and for industrial vegetation control.

10. List 3 practices guidelines for preventing environmental harm from mosquito larviciding by aerial application.

CHAPTER 6 - PEST MANAGEMENT

Goals of this Chapter

When you have completed this chapter, you should be able to:

- describe the essential components of an Integrated Pest Management program
- describe the general characteristics of weeds
- describe the general characteristics of insects and mites
- be familiar with the causes of disease in plants
- describe general characteristics of herbicides
- describe general characteristics of insecticides and miticides
- describe general characteristics of fungicides
- outline general considerations for pest management by aerial application in:
  - agriculture
  - forestry
  - industrial vegetation management
  - biting fly control.

Introduction

Aerial applicators may undertake pest management in agriculture, forestry, industrial vegetation management and aquatic pest control. In these situations, applicators can be faced with a diversity of pests including weeds, insects, diseases, etc. Aerial applicators should have sufficient understanding of the biology of these pests to communicate with pest management specialists about pest and pesticide characteristics important for control such as:

- general classification of pests
- vulnerable pest stages
- location of pests
- timing of application
- mode of action of pesticides
- integrated pest management

Pesticide applicators must also be familiar with the principles and practices of Integrated Pest Management (IPM) and should try to ensure that all applications are carried out so as to be consistent with IPM program objectives.

Integrated Pest Management (IPM)

A general definition of IPM is: a pest management approach that uses all available techniques in an organized program to suppress pest populations in an effective, environmentally sound and economical manner. These techniques can include cultural controls, biological controls, pest resistant crop varieties, pheromones and pesticide applications.

An IPM program is based upon the concept of **prevention** by using sound planning and good management of the site to prevent or minimize pest problems. Instead of applying pesticides according to a spray schedule or time of year, treatments in an IPM program are made only when monitoring inspections show that they are required. This eliminates unnecessary pesticide use and can also reduce the cost of managing the pests.

IPM programs have several advantages over conventional spray programs:

- provide long-term solutions to pest problems
- reduce the amount of pesticide used and the associated potential environmental and health impacts
- enable pest managers to control pesticide resistant pests

Ideally, an IPM program starts with prevention. In reality, however, when an applicator is called to deal with an existing pest, the immediate problem must be dealt with before future prevention is considered. For an existing pest problem, IPM involves the following five sequential elements:

1. Identification

It is essential to correctly identify insects, diseases, competing vegetation and other problems to plan effective management programs. With the problem identified, the pest manager can then find out about the biology, life cycle, preferred habitat and other characteristics of the pest. Having this information helps the manager to plan preventative measures, to know where and when to monitor and what kinds of treatments will be effective.

2. Monitoring

Monitoring consists of inspections or sampling programs, done regularly to get an estimate of the size, extent and location of pest populations. Other factors might also be monitored, such as numbers of beneficial species present or weather conditions that lead to disease outbreaks. It is essential that written records be kept. Monitoring is used to provide the information for decisions about whether or not treatment is needed and, if so, the timing of treatments. How often to monitor depends on the situation. For example, monitoring for insect pests in horticultural crops is usually done weekly. In forestry, however, site inspections for competing vegetation might be done annually or only a few times in the early years of the production cycle.

3. Action Decisions

Action decisions are made using information from the monitoring program. The information is used to determine if there is a risk that the population of pests will reach the injury level (also called injury threshold). The injury level is the point at which a pest population reaches the level that justifies the cost of treatment. All treatment actions have financial costs, as well as other impacts, such as on wildlife or fish habitat and on beneficial organisms that contribute to pest control. These costs must be weighed against the benefits to determine whether or not treatments are justified and, if so, what types of treatments would be best.

In agriculture, economic injury thresholds have been established for specific pests in some crops. These are calculated using values for losses in yield or quality, costs of labour and treatments and other factors. In the case of a nuisance pest, such as mosquitoes, an injury threshold might be based on the numbers of mosquitoes that could be tolerated by the residents of the area. For problem vegetation, injury thresholds could be based on average height, type of species present, density or other characteristics of the plants that are important in relation to their impact on the crop. For example, red alder might be a problem for crop trees only when it reaches more than a certain number of stems per hectare. That number would be the injury level.

Once an injury level has been established, the pest manager must also decide on the timing of any treatment actions that would keep the pest population from reaching the injury level. This is the action level (or treatment threshold) and it depends on the type of treatments that will be used as well as on the biology of the target pest. For example, some treatments, such as dormant oil sprays or cultivation of crop weeds are only applicable at certain times of the year. Others, such as the bacterial pesticide, BTI, used on mosquito larvae, affect only a particular life stage of the pest and therefore, must be used when that stage is present. For some agricultural pests the economic injury levels and action levels are well defined, but in other sectors, such as vegetation management, establishing action levels is a relatively new idea and much more work and experience is needed.

4. Treatments (Control Options)

The choice of treatments depends on what has been identified as the pest and where it is occurring, as well as the cost, availability and effectiveness of the treatments. Monitoring is used in determining where and when to apply treatments for the best effect. Treatments include many different types of controls that might be used alone or in various combinations to fit a particular site. Examples are:

- **Cultural controls**, such as using pest resistant cultivars of crops, choosing appropriate plants for the conditions, rotating crops to reduce weed, nematode and other pest problems.

- **Mechanical controls**, such as the use of machinery for brushing, mowing or cultivating; also tractor mounted vacuums, electronic fly traps and other equipment.

- **Physical controls**, such as mulches to suppress vegetation, screens to keep out insects and barriers to prevent deer browsing. Using extreme heat (such as controlled burning in forestry) or cold (such as winter chilling grain in elevators) to kill pests could be considered physical control.

- **Biological controls**, which is the use of living organisms to control pest organisms. These include beneficial insects and mites released in orchards to control pests, grazing animals used to control vegetation, disease organisms that act as herbicides or that infect insects.

- **Behavioural controls** use the insects' own behaviour against it. For example, synthetic attractants are used to lure mountain pine beetles to trap trees and dispensers of sex pheromones are placed in apple orchards to interfere with the mating behaviour of codling moths.

- **Chemical controls**, such as herbicides, insecticides, fungicides, deer repellents and other registered products that control, suppress or repel pests.

5. Evaluation

Evaluation is the final, and some ways the most important, element of an IPM program. The pest manager reviews the results of the IPM program (sometimes by conducting follow-up inspections), as well as reviews monitoring methods and records, injury and action thresholds and treatment decisions. This information is used to plan future improvements to the IPM programs as well as to determine costs and benefits of treatments.

The factors that must be considered when planning an aerial pesticide application, and the practical implementation of IPM, vary with the sector and are described later in this chapter. However, the five main elements discussed above are fundamental components of any IPM program. Aerial applications are primarily used to control agricultural crop pests, vegetation and insects in the forestry sector, industrial vegetation and biting flies (such as mosquitoes and black flies). The applicator's first responsibility, which is common to all these sectors, is to ensure that the target pest is correctly identified and understood.

Pest Biology

Implementation of an effective pest management program requires an understanding of the target pest, whether it be a weed, an insect or mite or a disease organism. The pest must be correctly identified as to species, life stage and population level before making the decisions whether to apply a pesticide, which pesticide to use and when and how to apply it.

The following sections outline the basic characteristics of the groups of pests with which aerial application is most commonly used.

Weeds

A weed is a plant that grows where it is not wanted. Weeds compete with other plants for food, water, sunlight and space.

Weeds may have one or more of the following undesirable characteristics. Weeds may:

- compete with desirable plants for light, water and nutrients
- harm people or animals
- be alternate hosts for other pests
- be aesthetically unpleasing.

Types of Weeds

Weeds can be classified according to how long they live.

Annual weeds complete their life cycle within one year. Many annuals produce numerous seeds to ensure their survival. Annuals can be divided into two groups:

- **Winter annuals** germinate in the fall, overwinter and die the following summer.

- **Summer annuals** germinate in the spring and die in the fall of the same year.

Biennial weeds live more than one year, but less than two years. They grow from seed which usually germinates in the spring. The first year they store nutrients, usually in short fleshy roots. The foliage forms a rosette of leaves. The next spring the plant uses the stored nutrients and grows vigorously. It produces seed in the summer or fall and then dies.

Perennial weeds are plants that live more than two years. Often no seed is produced the first year. Thereafter, seeds can occur every year for the life of the plant. Most perennial weeds spread by seed. Many also spread by other plant parts such as creeping stems, creeping roots, rhizomes, bulbs and root pieces. There are shallow-rooted and deep-rooted perennials. Perennials may be considered herbaceous or woody.

- **Herbaceous perennials** die back to their roots each year and have relatively soft stems.

- **Woody perennials** do not die back to their roots; rather, they grow from their branches or twigs in the spring.

Plants are also classified according to their structural similarities, including the following types:

- **Conifers** have needles or scale-like leaves and produce seeds in cones. Most are evergreen. They are often referred to as softwood trees. Pine trees (*Pinus sp.*) are examples of conifers.

- **Deciduous** trees generally have broad leaves and produce seeds through flowers and fruit. They are often referred to as hardwood trees. Oak trees (*Quercus sp.)* are examples of deciduous trees.

- **Flowering plants** produce seed from flowers. They include herbaceous (soft-stemmed) plants such as grasses, thistles, dandelions, etc. and woody plants such as various brush, shrub and tree species.

Weed Identification

The following characteristics of plants are used in their identification:

- leaves:
  - compound or simple
  - shape
  - margin
  - surface (smooth or hairy)
  - arrangement along the stem
- stems:
  - branching habit
  - woody or herbaceous
  - upright or spreading
- flowers:
  - compound or single
  - arrangement
  - number of petals, sepals reproductive parts
  - seeds
- roots:
  - fibrous, creeping, tap

Identifying Leaf Stages

The identification of plants is a challenging task. If you are not able to identify a weed, numerous sources of expertise are available including nurseries, colleges and government departments.

Since the timing of the application of herbicides is often based on the leaf stage of the weed or desirable plants, identifying the leaf stages of plants and weeds is important. In addition, herbicides are often effective only when desirable plants and weeds are at a certain stage of growth. Sufficient leaf area is important for effective control. Weed control may not be achieved or desirable plants could be damaged if applying too early or too late.

Weed size and leaf numbers change rapidly. Avoid applying herbicides past the stage when they will not be effective. If you have difficulty in identifying the weed by its leaf stage, seek help from your local extension control specialists.

Leaf stages of broadleaf plants: The first leaves are the **cotyledons**. These are also called the seed leaves. They are paired and usually a different shape than the true leaves. On a few plants they stay beneath the soil surface. **True leaves** are the second leaves to appear and are the first leaves that can be used for identification of the species (Figure 5a).

True leaves are arranged along the stem as follows:

- **Alternate leaves** emerge singly from nodes from alternate sides of the stem and are not directly opposite each other.

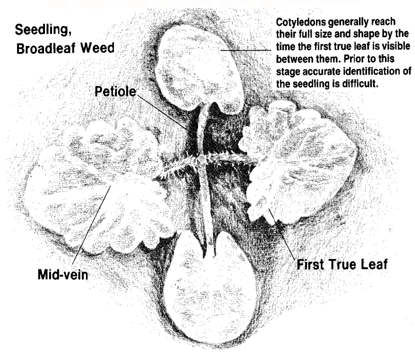
- **Opposite leaves** emerge as pairs from the same node of the stem.

! **Whorled leaves** emerge as three or more leaves arising from each node on the stem.

When counting leaf numbers, count each true leaf whether alternate, opposite or whorled, unless the recommendation refers to the number of whorls or pairs of leaves. Cotyledons are not counted when determining the number of leaves.

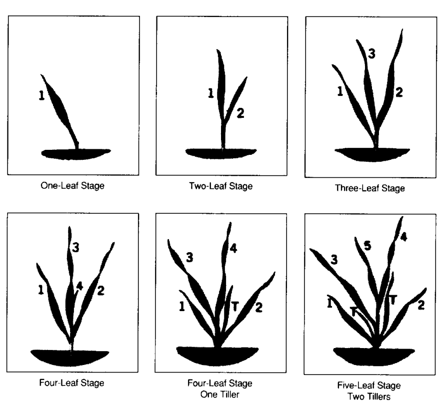
Some plants have compound leaves (e.g., clover). **Compound leaves** are made up of several leaflets. Each compound leaf is counted as one leaf. Do not count each leaflet.

Figure 5a. Leaf Stages of a Broadleaf Plant



Leaf stages of grasses: The first leaf is a single coleoptile. The true leaves emerge alternately along the stem. To establish the leaf stage, count all the leaves on the main shoot. Do not count the coleoptile or tillers in a leaf count. **Tillers** are the secondary shoots of a grass plant which emerge from the base of the leaves, generally at the three to five leaf stage (see Figure 5b).

Figure 5b. Leaf Stages of Cereals



Insects and Mites

There are over 50,000 species of insects and mites in Canada. Only a few are pests. Insects and mites are only pests when they damage property, crops, food, feed and livestock; and when they carry diseases affecting man or animals; or when they are a nuisance.

Pest insects and mites are present in low numbers for most of the time until conditions become right for their populations to expand rapidly. In such cases, they may multiply so fast that natural enemies such as birds, predatory insects and diseases cannot keep the population levels in check.

Sometimes pests are introduced species **S** that is they have been transported from other geographical areas. In the new location there may be no natural enemies to control them and the populations can then expand rapidly, causing damage.

Insect and Mite Characteristics

Insects with a few exceptions, have six (6) legs, an outer skeleton, and three (3) body sections (head, thorax and abdomen) in the adult stage. They may vary in size from scarcely visible to several inches long. Adults of some insect species have two wings; others have four and some have none.

Mites are related to spiders and ticks. They are extremely small (0.1 **S**1 mm in length), have no wings and generally have 8 legs.

The majority of insects and mites are not considered pests; some are beneficial, helping to control pests or contribute to crop production. These should be protected wherever possible. They include predators, parasites and pollinators.

Predatory insects prey on and eat other insects or mites. For example, adult lady beetles and their larvae consume many kinds of soft-bodied insect pests. They are voracious feeders on aphids.

Lacewing larvae are predacious on a number of insects including aphids, scales, mites and mealybugs. The minute pirate bug feeds by sucking body fluids from aphids, thrips, mites and young scale insects. Adult syrphid flies, which resemble bees, are important in regulating aphid populations in many field and vegetable crops.

Parasitic insects live on or in other insects or weeds (hosts), causing some harm and usually death of the host. These parasites can affect the eggs, larval, pupal or adult stages of an insect. Some well-known parasites are the tachinid flies. Their larvae develop and feed on the caterpillar stage of many destructive insect pests such as cutworms, armyworms, codling moth, hornworms, cabbageworms and grasshoppers.

There are a number of parasitic insects belonging to the bee and wasp group (ichneumonids, brachonids and chalcids). Their life cycles are often closely synchronized with their host. The adult females lay eggs in or on the host and the parasitic larva consumes the internal organs of the host, eventually killing it. Some native and introduced species help regulate populations of aphids, weevils and cutworms.

Pollinating insects are essential to the pollination of many berry, fruit and seed crops. Examples are honey bees and leafcutter bees, bumble bees and other wild bees as well as some flies, butterflies and moths that feed on nectar and pollen of flowers.

Insect and Mite Life Cycles

Knowledge about insect and mite reproduction and development can be used to apply control measures at times when pest species are most susceptible.

Most insect and mite reproduction results from males fertilizing females. Some exceptions exist whereby reproduction can occur without mating (e.g., aphids). A few insects give birth to live young (e.g., aphids); however, life for most begins as an egg.

Eggs may be deposited individually or in masses in the soil or on plants, animals or structures. Temperature, humidity and light conditions influence the time of hatching.

When an insect or mite hatches from an egg, it begins to feed and grow until its skin restricts its growth. The animal then sheds its skin (molts), and a new skin is formed. The last growth stage is the reproductive adult.

The common stages of growth are:

- egg
- larva
- nymph
- pupa
- adult

Two sequences of insect stages are:

- Egg to nymph to adult: a nymph is similar in appearance to the adult but is wingless and lacks reproductive organs. For example, aphids and grasshoppers have the nymph life stage.

- Egg to larva to pupa to adult: the larva is very different from the adult and is usually soft-bodied in appearance (e.g., caterpillars, loopers, grubs, maggots); the **pupa** is a non-feeding stage during which a complete change of shape occurs; and the **adult** is the reproductive, winged stage. For example, mosquitoes, moths, beetles and flies have the larval life stage.

Mites generally go through four stages:

- egg to larva to nymph to adult: both larval and nymphal life stages usually consist of several substages referred to as **instars**.

Usually, the best time in the life cycle for control is during the early instars, — young nymph or larva. The last two larval or nymphal stages generally cause the heaviest feeding damage. Pesticide control at these later instars may reduce pest populations but may not prevent significant feeding damage to the crop.

Diseases

Disease may result in plants developing abnormally. Diseased plants may have underdeveloped roots, stunted stems, curled leaves or other abnormalities.

Causes of Disease Symptoms

Disease-like symptoms are caused by living organisms (i.e., fungi, nematodes) or by insect damage (e.g., gall forming insects), herbicide damage, environmental stresses, with or without actual disease infections. It is important to correctly identify the cause of the symptoms so that an effective treatment can be chosen. Problems related to environmental stress cannot usually be controlled by pesticides.

Unfavourable environmental conditions that stress plants and cause abnormal growth or disease-like symptoms include extremes of light, temperature, water or nutrients and toxic chemicals. Plants weakened by environmental stress are more likely to be infected by pests. Recognizing and relieving the stress will help prevent invasion by insects or infectious diseases. Examples of stresses that cause disease symptoms include:

- frost damage
- excess moisture, which can result in oxygen deficiency
- nutrient deficiencies or excesses.

Microorganisms can cause disease symptoms. Pest microorganisms include:

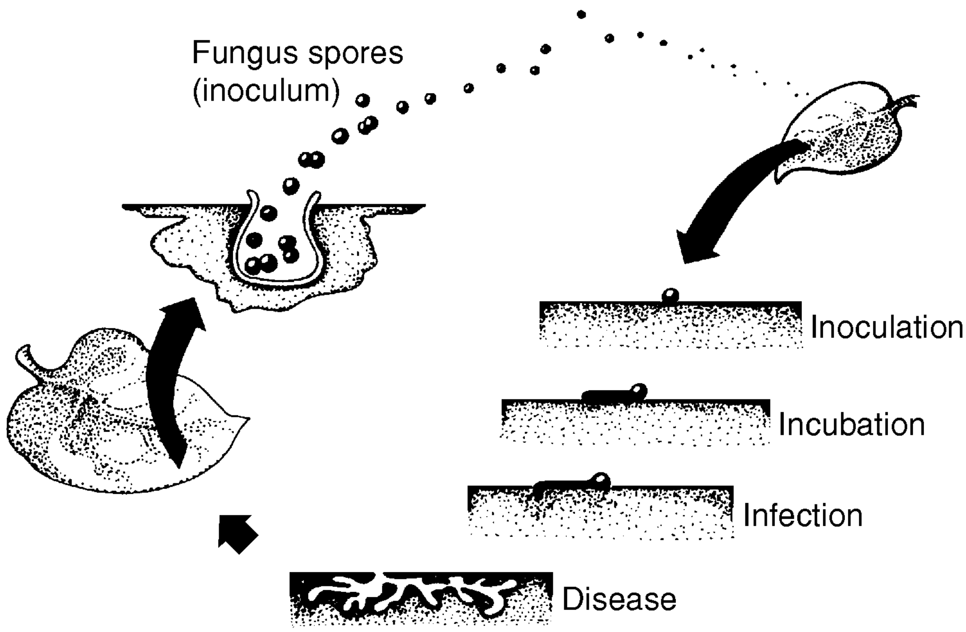
- fungi
- bacteria
- viruses
- nematodes.

The organisms are usually identified by the characteristic symptoms that they produce. Sometimes the organisms can be seen with the naked eye or they are identified through microscopic investigation or laboratory analysis.

Fungi: These are the largest group of organisms that cause plant diseases. They are simple plants that feed on living or decaying organisms. This group includes molds, mushrooms and rusts. Most fungi reproduce by tiny spores. When spores germinate, they usually produce threadlike filaments that can infect the host, absorb nutrients and give off toxins that cause disease symptoms.

Fungi are spread by spores or tiny pieces of the fungus. Movement of infected plants, plant parts and soil may also spread the fungus.

Figure 6. Example of a Life Cycle of a Fungus in a Plant Leaf



The life cycles of many fungi follow a similar sequence. The following is a typical example of the sequence: the fungi stay on a diseased leaf over winter. As the weather becomes warmer in spring, the fungus becomes active and produces spores. The spores are released into the environment and are moved by wind and water. Some land on healthy leaves of a plant. If environmental conditions are poor for germination, the spores may die, be washed off by rain or remain dormant. However, if environmental conditions are good, the fungal spores will germinate.

While spores, themselves, are fairly resistant, the fungus is most vulnerable to fungicides just after germination of the spore. Infection begins when the fungus enters plant tissues. Once inside the plant, the fungus is protected and difficult to control; although a systemic fungicide may control the disease, if applied before the infection is too severe.

When the plant responds to an infection by growing abnormally, it is said to be diseased. Some disease symptoms that may be caused by fungi include cankers, dieback, galls, leaf spots, rots, rusts and wilts.

Bacteria: These are one-celled organisms which can only be seen with a microscope. Bacteria can cause major plant diseases. They usually enter a plant through natural openings or wounds. Under favourable conditions, bacteria reproduce very quickly, using the plant as a source of food. Bacteria are spread by wind and rain or by contact with animals or equipment. Some blights, galls and rots are caused by bacteria.

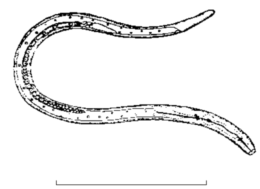
Viruses: These are sub-cellular particles that can only grow within host cells. They cannot be seen with an ordinary microscope. Viruses cause diseases that often reduce plant vigor and crop yields. Viruses reproduce only when they are in living cells. Viruses can be spread by mechanical means (i.e., during pruning or harvesting), in propagation material, seeds, tubers and other plant parts) or by vectors (i.e., insects, mite, nematodes, fungi).

Mosaics, ringspot and leaf roll are examples of diseases caused by viruses. *No pesticides are available to control viruses directly.*

Nematodes: These are small thread-like worms which may feed on plant roots, stems and leaves. They can affect the movement of water and nutrients in a plant. They also create wounds which may allow fungi or bacteria to enter.

Some symptoms that can be caused by nematodes are:

- wilting
- stunting
- lack of vigour
- growth deformities.



Approaches to Disease Management

The following three conditions must be present for a infectious disease to develop:

- a disease causing organism (pathogen)
- a host susceptible to the disease
- an environment favourable to the disease organisms and/or unfavourable to the host.

Taking away or changing any one of these three conditions will control the disease. For example, a disease problem can be prevented by keeping the organisms out of an area, using strains of plants that are resistant or not affected by the disease, reducing the population of disease causing organisms or manipulating the environment to favour the host, but not the disease organism.

Pesticide Characteristics

Pesticides are first and foremost classed by the category of pest against which they are active: herbicides, insecticides, miticides, fungicides, nematicides, rodenticides, etc. Additional classification may be by the mode of action, e.g., systemic. The most detailed classification involves the actual chemical family to which the pesticide belongs, e.g., organophosphate.

Herbicides

Types of Herbicides

Herbicides are described according to:

- selectivity

- mode of action
- timing of application
- residual effectiveness.

Selectivity: Selective herbicides kill or damage only certain plants; non-selective herbicides kill or damage all plants on a treated area.

Mode of Action: Herbicides kill plants in different ways, including:

- **Contact herbicides** damage parts of the plant contacted by the herbicide. There is little or no movement of the herbicide in the plant. Contact herbicides are effective against annual weeds but they only “burn off” the tops of perennial weeds. “Burn off” may be useful in preventing seed production because the plant top is killed before viable seeds are produced.

- **Systemic herbicides** enter the roots or above ground parts of plants. These herbicides move or are translocated in the plant. Effects may not show for a week or more after treatment. Too much herbicide on the leaves may kill plant leaf cells too quickly and prevent translocation to the site of action in a plant.

Timing of Application: Herbicides may be applied at different stages of crop or weed growth.

- **Pre-plant**: The herbicide is applied to the soil before seeding or transplanting. Pre-plant treatments are usually incorporated into the soil. These are called pre-plant soil-incorporated treatments.
- **Pre-emergence**: The herbicide is applied to the soil after planting but before the emergence of the specified crop or weed. Pre-emergence may refer to the germination of either the weed or the crop. Pre-emergence herbicides control weeds before or soon after they emerge.

- **Post-emergence**: The herbicide is applied after the specified crop or weed has emerged. The application may be soon after emergence or up to when the plant achieves a specific height or number of leaves. Post-emergence herbicides control established weeds.

Residual Effectiveness: This refers to the ability of the herbicide to control weeds over time due to the persistent nature of the pesticide. Some residual herbicides impact the germination of weed species for more than two years. The incidence of successful germination and emergence increases with time as residual activity in the soil declines.

Non-residual herbicides are quickly inactivated in the soil after application by micro-organisms, photodegradation, etc.

Factors Influencing Herbicide Efficacy

There are many factors which influence herbicide efficacy. These include:

- shape and surface of leaves
- weather
- age of the weed
- nutrition
- soil type and moisture
- cultivation
- resistance.

Shape and surface of leaves: Thin upright leaves are hard to cover with spray. Hairy or waxy plant surfaces may reduce the herbicide contact. Surfactants or surface active agents can be added to the herbicide formulations to increase the wetting ability of the spray so it will not bead, or to cut through waxy surfaces and aid penetration into the leaf. They should be added only if specified by the herbicide label.

Weather: Temperature, humidity, rain and wind may affect herbicide efficacy. Moderate weather conditions are usually better than extremes. The herbicide label will usually indicate what weather conditions should be avoided.

Cool or dry conditions slow the production and movement of nutrients in the plant and reduce the movement of systemic herbicides. Hot dry weather may make the herbicide evaporate quickly from the weed leaves and, therefore, reduce effectiveness. Warm temperatures and high humidity usually result in the greatest penetration of leaf surfaces. However, some contact herbicides (e.g., bromoxynil) work better in cool temperatures.

Rain during or after an application can wash the herbicide off plants. However, some soil-applied herbicides require irrigation or rain after application to carry then down to the root zone.

Wind can cause drift and prevent the herbicide from reaching the target.

Age of the weed: Herbicides are often more effective on young, rapidly growing weeds. Systemic herbicides that move with the nutrients and water can spread faster in rapidly growing, younger weeds than in older plants. Herbicides are less likely to kill plants that are in full flower or producing seed.

Perennial weeds often become more resistant to herbicides as they grow older. However, they may become susceptible again in the bud or early flowering stage. This is because at this stage the herbicide will move with the food supply to the roots or spreading rhizomes and kill the weed.

Nutrition: Herbicides work best when the weeds are growing vigorously. Soil nutrients are needed for good weed growth and soil applied herbicides are taken in through the roots along with the soil nutrients.

Soil type: Generally, more herbicide may be needed for organic (peat or muck) or fine textured soils (clay or silt). These soils hold more herbicide on the soil particles and this reduces the amount available for weed control. Sandy soils usually need less herbicide. The herbicide label may state how much is needed for the different soil types. Never use more than the label rate.

Soil-applied herbicides generally work best in a warm, moist soil. The moisture helps the herbicide move to the weeds.

Cultivation: Cultivating before a herbicide application can make herbicides more or less effective depending on the weed and the herbicide. Some weeds may be weakened by cultivation and become easier to control while other weeds may be broken into pieces and be harder to control. Read label directions before cultivating to see if cultivation will be beneficial for herbicide application.

Cultivation prior to planting encourages weed seeds to germinate. When weeds do emerge they can be sprayed with a non-selective herbicide and then the crop can be planted.

Resistance: In recent years, the number of herbicide-resistant weeds has increased.

Herbicide-resistant weeds arise following repeated use of the same herbicide (or herbicide group) for a number of years on the same area. To avoid development of resistance you should:

- rotate herbicide usage so that the same herbicide is not used year after year in the same area
- use tank mixes where both active ingredients within the tank mix may act to kill the same weed using different mechanisms of action.

Insecticides and Miticides

Types of Insecticides and Miticides

Insecticides and miticides should be used in a way that minimizes the negative impact on beneficial insects and the environment.

Insecticides and miticides are often described according to how they work (mode of action).

Contact Pesticides: These must come in contact with the pest to be effective. They can be applied to the pest or on surfaces that pests touch. Some contact insecticides have a residual effect and can kill insects for some time after they are applied.

Systemic Pesticides: These enter plants and flow in the sap. Insects or mites which suck the sap are killed. Some pesticides are both systemic and contact.

Suffocating Insecticides/Miticides (usually oils): These clog the breathing system of the pest and may also affect egg survival.

Growth Regulators: These act like the organism's own hormones. They affect normal development and the pest dies before it becomes an adult or before it can reproduce.

Attractants: These are chemicals that may attract female insects for egg laying or attract male insects to artificial female traps.

Microbial Pesticides: These contain microbes (tiny organisms such as bacteria). They are poisonous only to certain classes of insects. After ingestion, the microbe or a poison produced by the microbe kills the insects. To date, the various forms of *Bacillus thuringiensis* (referred to as Bt) are the only commonly available microbial insecticides.

Factors Influencing Insecticide/Miticide Efficacy

Timing of application: Insects/mites may need to be present or occur in a specific stage of development for a pesticide to be efficacious (i.e., effective).

Control during the early larval or nymphal stages requires careful monitoring of pest populations in order to achieve effective results of control. The later instars are generally less susceptible to pesticides. The eggs and pupal stages are not generally affected by most insecticides or miticides. It is difficult to control pests in these stages because these are often inactive, not feeding or are inaccessible (e.g., underground or in cracks or crevices).

Control of the early life stages of insects and mites is effective in preventing or suppressing current feeding damage, while control of the adult stage reduces subsequent generation numbers.

Weather conditions: Temperature, humidity and rain can alter the effectiveness of pesticides directly or affect the activity of the pest or its susceptibility to pesticides.

Resistance: Heavy reliance on chemical control methods has led to the development of pesticide resistance in insects and mites. A pest that is resistant to one pesticide is often resistant to others in similar groups and in different groups that work with a similar mode of action. If a pesticide is not working, or if it must be used more often than normal, pests may have developed a resistance to it.

Resistance has become a very serious problem to the pest-management industry.

The applicator can slow the development of resistance to a chemical pesticide by:

- using a non-chemical control method
- using pesticides only when required
- alternating pesticides from different groups (i.e., a carbamate, then a synthetic pyrethroid)
- developing an effective integrated pest management (IPM) strategy.

Fungicides

Fungicides are often described according to how they work (mode of action). Fungicides are used to prevent or eradicate diseases caused by fungi.

Types of Fungicides

Protectant fungicides: These provide a protective film of fungicide on or the host to prevent fungal spores from germinating. Protectant fungicides must be applied before the fungi reach the infective stage. After the plant is infected the fungicide normally will not kill the fungi inside the plant but it can protect the plant from further infection. New plant growth that appears after treatment is not protected; therefore, re-application is required. Protectants can be applied to seeds, foliage, flowers, fruit or to roots. Most fungicides used in control programs are protectant fungicides.

Eradicant fungicides: These kill fungal organisms that have infected but have not become well established within the plant. Eradicant fungicides have limited value for fungi that are well established within plants. Only a few fungicides are eradicants.

Systemic fungicides: These are not common. They are absorbed by plants and move within them. They may act as protectants, eradicants or both. Once inside the plant, systemics move to new areas of plant growth.

Factors Influencing Fungicide Efficacy

Timing of Application: To be effective, the fungicide should control the fungus before or during the infection period.

Fungus Life Cycle and Weather: The frequency of applications varies depending on the type of fungus, the fungicide and the weather. If the fungus has a short life cycle and there are good conditions for its growth, it can have many infection periods and many applications may be needed. Rain, rate of plant growth and the type of fungicide also affect the frequency of treatments. If the fungicide is washed off, if new leaves grow or if the fungicide breaks down quickly, applications may need to be repeated.

Resistance: Due to their rapid rate of propagation, disease-causing fungi are particularly prone to the development of resistance to certain fungicides or groups of fungicides. Repeated application of the same fungicide increases the risk that resistance will develop.

Pest Management Considerations by Sector

Agricultural Pest Control

Aerial applications in agriculture are used to control a wide range of weeds, insects and diseases that affect crops. As with any type of treatment, agricultural pesticides should be applied only when they are a component of an integrated pest management program. The applicator should review the proposed program in relation to the basic elements of IPM.

- The applicator must ensure the pest is properly identified and verify that the pesticide is registered for use on the target pest and crop.

- Pesticides should only be applied when a monitoring program has shown they are necessary. Many horticultural growers now employ IPM consultants or use IPM scouting services provided by packinghouses or other agencies. These services identify pests, monitor pest populations and make recommendations on treatments and the timing of pesticide applications. Growers may receive recommendations directly from crop scouts or from message systems via telephone or computer bulletin boards.

- As an aerial applicator you should be aware that the timing of sprays, particularly for control of diseases, is critical to the success of a pest management program. It is essential that you follow recommendations as closely as weather and operational factors allow.

- Where scouting recommendations are not available, you should ensure that recommendations by provincial authorities or pest management specialists have been checked to determine that the timing and extent of the application is justified, according to the life stage of the pest and the expected distribution of the pest population in the field.

Forestry Pest Control

Aerial application of pesticides in forestry is generally used for vegetation and insect control.

Vegetation Control

Vegetation management objectives include:

- site preparation
- stand tending.

Site Preparation: Site preparation refers to activities to improve a site for artificial or natural regeneration of desired tree species. Herbicides may be aerially applied to prepare sites for artificial or natural regeneration of desired tree species under one of the following conditions:

- when control of vegetation on old fields or forest sites is required to reduce competition that, if left untreated, is capable of causing seedling mortality or severe growth loss in the first several years of seedling development

- after a stand is harvested to inhibit sprouting or suckering of non-crop, woody vegetation that is widespread or has the potential to become widespread and is, or may be, in sufficient abundance to dominate the site and limit the success of reforestation efforts

- for desiccation of non-crop woody vegetation to facilitate controlled burning

- before a stand is harvested through stem injection, or spot (i.e., localized), band (i.e., strips or rows of spray) or broadcast (i.e., coverage of entire area) application to prevent the sprouting or suckering of competitive, non-crop, woody plants

- in addition to mechanical site preparation equipment or the application of controlled burn that will contribute to site degradation or excessive site disturbance or destruction of advanced growth

- when areas previously site prepared with the use of controlled burn or mechanical equipment must be “held over” for the renewal treatment (for example, appropriate nursery stock or seed is not currently available)

- for any other judicious use that, based on experience and professional judgement, will enhance reforestation success and/or reduce the need for future tending operations (herbicide or otherwise).

Stand Tending: Stand tending refers to any operations designed to improve the survival, height growth, diameter growth, biomass production or composition of a young forest stand. This may include **brushing**, which is the management of vegetation competing with seedlings or crop trees for light, moisture and nutrients or **conifer (or crop) release**, which refers to management of vegetation that is overtopping or surrounding crop seedlings or trees to promote crop growth to a free growth stage (when they have overgrown competing plants). The aim is not to kill all competing vegetation but to restrict its growth long enough to permit young desired trees to dominate.

All herbicide applications in forest management must follow the requirements established by the label and regulatory agencies.

Herbicide Disadvantages: Herbicide application programs have the following disadvantages:

- potential effects on fish and wildlife
- contamination of drinking water if not used properly
- few registered herbicides available that are suitable for some site conditions
- public concern about the use of chemicals in the environment.

Herbicide Advantages: Herbicide application programs have the following advantages over other control methods:

- less resprouting of woody species
- little or no disturbance of the soil, which is desirable when sites are located on steep slopes in fragile soils, particularly when close to streams or other waterbodies
- generally less expensive
- safer to workers.

Timing of Herbicide Uses: Herbicides should be applied when the dominant problem vegetation species are most susceptible to the herbicide and when desirable species are relatively resistant or will sustain little damage.

Herbicide use in different seasons is characterized as follows:

- **Budbreak sprays** (late winter or early spring when new leaves of target species are just beginning to form). Herbicide absorption at this stage is mainly through the bark of stems and branches. Target species can be susceptible to some herbicides just after budbreak. Conifers are relatively resistant to herbicide budbreak.

- **Early foliar sprays** (late spring). Most plants are susceptible to herbicides during this time of active growth. This is a poor time for brushing and conifer release unless conifers are protected. However, it is an effective stage for site preparation.

- **Late foliar sprays** (middle to late summer). These are less effective on shrubs than earlier foliar sprays. Conifer resistance to herbicides increases after growth ceases and new bud formation.

- **Fall sprays** (late August to October). Conifers are resistant to some herbicides. This is a good time for control of some deciduous brush species as herbicides can be translocated to roots along with food reserves. However, it is a less effective time for control of many herbaceous species since growth may have ceased.

Insect Control

The objectives of aerial application for insect control in forestry include the following:

- eradication (complete elimination of pest, e.g., Asian gypsy moth)
- suppression of an insect epidemic (reduction in population e.g., tent caterpillar control)
- protection of trees from defoliation (e.g., spruce budworm control)

There are relatively few species of insects that are severe pests in forestry, but some cause significant economic losses. The two main types of forest insect pests that can cause widespread damage are woody tissue feeders and defoliators.

Woody tissue feeders: The most damaging of woody tissue feeders are the bark beetles, which cause very high losses in mature and overmature stands. These insects bore through the bark and chew out galleries in which to lay their eggs. The eggs typically hatch in a few weeks and the larvae stay in the tree until the following year, when they emerge as adult beetles. Newly infested trees remain green until the following summer and then die. Bark beetles cannot be controlled by aerial sprays.

Defoliators: Most attacks on needles or leaves are made by a group of insects known as defoliators. The larvae (caterpillars) of moths and sawflies are the most important defoliators of conifer and deciduous trees. Eggs laid by adults hatch into caterpillars that fed on new or old foliage, depending on the species. When the moths emerge they usually can fly and may be carried by wind for distances of 100 km or more.

Defoliators do not usually kill trees immediately; depending upon the species, one or several years of severe defoliation will cause tree mortality. The needles on the branches turn brown, the trees develop a scorched appearance and normal growth is reduced. This lessens the economic value of a tree and makes it more susceptible to other insects and diseases. If several attacks occur during the life of a tree, growth loss can be substantial. An infestation can spread very rapidly from a patch of trees to thousands of hectares in a couple of years. After a period of little to no activity, populations can suddenly explode, lasting two to ten years, followed by a natural decline. Defoliators are vulnerable to parasites, predators, diseases and extremes in temperature.

Insecticides may be used to control the spread of a defoliator or to protect a stand of crop trees from excessive defoliation until an infestation has declined. A key factor in forest pest management is early detection and assessment of the type of infestation that may occur. When the chemical control option is chosen, it should be carried out early in the outbreak, when the area to be treated is as small as possible.

The microbial insecticide *Bacillus thuringiensis* (Bt) is now being widely used on defoliator larvae, in particular, moth larvae. Bt is viewed as being a much safer and environmentally acceptable alternative to most chemical insecticides. Bt's higher viscosity and tendency to settle out on standing require special attention. The timing with the use of Bt is critical with respect to larval development and weather conditions.

Other insect pests: Sucking insects and cone and seed insects cause damage in localized areas. These insects can be pests in seedling nurseries and seed orchards.

Industrial Vegetation Control

Industrial vegetation management includes control of undesirable vegetation on industrial sites, rights-of-way (e.g., rail, road, pipeline and hydro) and on public land. The reason for a vegetation problem should be evaluated before initiating controls. Vegetation management may include avoiding the creation of bare earth conditions, which are conducive to weed development, or may include enhancing desirable vegetation, not just treatment of weeds.

The tolerance for weeds differs for various site uses and should be established before controls are implemented. A control method should be selected only after a variety of alternatives have been considered. Herbicide selection must always be based on a site-specific prescription, considering conditions such as weed species, soil type, topography, proximity to water and land use. When economically feasible, selective removal of the target species is preferable as it will:

- reduce herbicide use
- preserve desirable vegetation
- safeguard the environment and health.

Aerial application of herbicides for industrial vegetation control is rare since it is not sufficiently selective to be used in a program that encourages desirable vegetation while eliminating undesirable vegetation.

Biting Fly Control

Control of mosquitoes and black flies is complex. It requires careful planning and execution to reduce populations to tolerable levels, and be economically and environmentally acceptable. Mosquito and black fly abatement programs should generally be conducted for a community rather than for individuals to achieve successful control. A critical part of a biting fly program is the careful mapping of breeding sites. Larvae found in field surveys should be identified before any control measures are taken. There are over 50 species of mosquitoes and many species of black flies in Canada. Most are not significant pests.

For mosquito control programs, habitat removal should be considered. Some habitats can be removed (i.e., drained) or modified (i.e., deepened) to make them unsuitable for mosquito development.

Pesticides for biting fly management may be directed against the larvae (larviciding) or adults (adulticiding). Best results are usually obtained by larviciding, because larvae are relatively confined and concentrated. Adults are widely dispersed and are less easily treated. Adulticiding should be used only as a last resort to kill adults migrating into an area.

Larvicides come in a variety of formulations including emulsions and granules. The latter are more suitable for application to sites with emergent or floating vegetation and can be applied by aircraft with less potential for drift. Application of larvicides must be made to areas that are known breeding sites when the majority of larvae are mid-way through their development and the majority of eggs have hatched. The application timing with respect to larval development can be critical, especially with certain pesticides. Check the pesticide label for direction on proper use.

Adulticiding programs for control of mosquitoes and blackflies are usually conducted only when their numbers are severely annoying. The abundance of biting flies may be determined by bite counts or by trapping to indicate when applications should start. Two approaches for adulticiding can be taken. For either approach, aircraft mounted equipment may be used.

- **Residual sprays to vegetation surfaces on which mosquitoes and blackflies rest**. Such sprays may be made where specific areas are to be protected or as a barrier treatment to prevent the migration of black flies or mosquitoes into an area (i.e., industrial work areas, private yards, parks and golf courses). Spraying should be done in late afternoon or evening, shortly before biting flies become active and according to regulatory requirements.

- **Space sprays (low-volume or fog) to kill flying mosquitoes and blackflies**. With space sprays, a cloud of small droplets (5-20 micron range) are suspended in the air, which drifts downward to come in contact with adult biting flies. The effective swath width should be about 100 metres. The sprayer should travel at right angles to the direction of the wind. Space sprays should be conducted when pest activity is at a maximum and winds are less than 10-12 km/hour. This usually occurs in the late evening, overnight and early morning.

Review Questions – Pest Management

Integrated Pest Management

1. What are the basic concepts underlying an Integrated Pest Management (IPM) program?

2. List the five main components of an IPM program for an existing pest problem.

Pest Biology

1. Define the terms annual, biennial and perennial weeds.

2. Explain the terms conifer and herbaceous.

3. Why is it important to know the leaf stages of weed and crop plants?

4. List 3 differences in appearance between most adult insects and mites.

5. At what life stage do defoliating insects generally cause the most damage?

6. List the various causes of disease-like symptoms.

7. List the three conditions necessary for the development of infectious disease symptoms.

Pesticide Characteristics

1. List 2 types of herbicides according to mode of action.

2. Describe how age of a weed may influence herbicide effectiveness.

3. Insecticides that affect the way an insect grows are called ...

4. List 3 types of fungicides named according to how they work.

Pest Management Considerations by Sector

1. Describe the decision-making process that should be implemented by the aerial applicator when approached to aerially apply a pesticide in a farm situation.

2. What is the difference between site preparation and stand tending?

3. What are 3 disadvantages of herbicide use in forestry?

4. List 4 types of forest herbicide sprays based on time of application.
5. List 2 major groups of insect pests that are problems in forest management.
6. Describe a possible disadvantage in using aerial application for achieving long-term industrial vegetation management objectives.
7. Why should mosquitoes be identified before implementing a mosquito treatment program?
8. What should a monitoring program be used for in a program to treat adult mosquitoes?

CHAPTER 7 - APPLICATION TECHNOLOGY

Section 1 — Application Systems

Goals of this Section

When you have completed this section, you should be able to:

- describe the major components of liquid and solid dispersal systems
- list the major types of navigation and swath guidance systems and indicate how each works.

Introduction

Aerial applicators should have a good understanding of how their application systems work. Application systems described in this chapter encompass dispersal systems and their components and navigation and swath guidance systems. This chapter also compares rotary- and fixed-wing aircraft.

Types of Aircraft

The selection of aircraft is an important first step in the management of an aerial application project. The successful applicator must know a great deal about the aircraft's capabilities and limitations to ensure the task can be carried out safely and effectively. Generally, aircraft selected should be as versatile as possible, allowing use for a wide variety of application work with the most economical cost per hour. The choice may be between a variety of fixed- and rotary-winged aircraft. While there has been a number of fixed-winged aircraft specifically designed for aerial application, this is not the case with rotary-winged aircraft. However, when configured for aerial application, rotary-winged aircraft may be even more suitable than fixed-winged aircraft for certain jobs.

The choice of the type of aircraft that is most suitable for a given project is a function of many considerations. In practical terms, the choice will be heavily influenced by the availability and price of aircraft. There are also many factors relating to the design of a project that influence the choice. Generally speaking, projects involving ULV (Ultra Low Volume) applications to large blocks may be best served by fixed-wing aircraft, which (on average) spray at a higher speed and carry more volume than helicopters. If treatment areas are small and the application requires larger volumes per unit area and lower speeds, helicopters would be favoured. Fixed-winged aircraft have to be operated from a fixed base, while helicopters can be paired with portable loading equipment. This is a factor when considering the spatial arrangement of treatment areas (i.e., grouped or scattered). Complex programs can often involve combinations of fixed- and rotary-winged aircraft of various sizes; each with their own situations where they are more suitable than other aircraft for treating certain areas.

The use of ground equipment together with aircraft is also an important consideration in any pesticide application program. Ground rigs can provide very precise placement of materials in smaller, confined areas not accessible by aircraft.

Some Comparisons of Rotary and Fixed-wing Aircraft

Unlike fixed-wing aircraft, no helicopter has been specifically designed for aerial application operations. The close maneuvering under high loads encountered in some aerial applications places a high priority on pilot skill and proper design of dispersal equipment. The greatest deterrents to helicopter use have been the low payload capacity, the high initial cost and greater maintenance requirements. However, the helicopter's ability to take off from and land in practically any spot large enough to clear the rotor (including platforms on service trucks) as well as to make shorter turns and to manoeuvre in confined areas frequently makes up for the smaller payload.

The following presents some operational considerations of rotary- and fixed-wing aircraft.

Cost: Helicopters require a greater initial capital outlay and are costlier to operate per hour compared to similar weight fixed-wing aircraft.

Operating base: Helicopters can operate from unconventional sites such as the edge of a field, road, small clearing or even from a pad on a loading truck, greatly reducing or eliminating unproductive ferry time. Fixed-wing aircraft are generally restricted to operating from established or temporary airstrips, which may not be conveniently located in relation to the areas being treated.

Spraying speeds: A helicopter can spray at very low airspeeds, allowing very heavy coverage not possible with fixed-wing aircraft.

Manoeuvrability: A helicopter can turn around high trees or other obstacles in an area that would normally be treated with trimming runs with a fixed-wing aircraft. This, combined with quicker turn-arounds at the end of a run, increases work rate and productivity, thereby partially offsetting the helicopter's lower payload and higher operating cost.

Spray distribution: At lower airspeeds (less than 40 mph) the helicopter's large down and aft airflow of the main rotor wake can be used to disperse the spray through a crop, including the undersurface of the leaves. However, at higher speeds the wake pattern becomes similar to fixed-wing aircraft. At speeds approaching 95 mph, the distribution pattern becomes uneven, requiring an asymmetric nozzle layout to give an even application. With fixed-wing aircraft normal wind turbulence is relied upon to aid spray deposition.

Spray gear: On fixed-wing aircraft spray gear is often windmill driven, hence their spray outputs are directly related to airspeed. Helicopter spray gear is driven mechanically, hydraulically or electrically with direct or indirect power from the engine. In helicopter installations, pump speeds and flow rate are constant, regardless of airspeed.

Contour and hill flying: When operating in hilly or mountainous regions, it is advisable that swaths be laid down along the contours. It is much easier for the helicopter to maintain a constant airspeed when flying the contours.

Obstruction clearance: Because of the generally greater visibility from helicopter cockpits, it is easier to see hazards and manoeuvre around obstacles than with fixed-wing aircraft.

Maintenance: Because of the complex power chain, power drives from the engine to the main rotor, the tail rotor, the control systems, etc., helicopters require greater maintenance than fixed-wing aircraft.

Loading and Centre of Gravity (C of G) limits: Most helicopters have small Centre of Gravity (C of G) variation limits, and loading becomes critical.

Rotary Aircraft — Special Considerations

Helicopter Operation

The effects of increasing density altitude are even more pronounced with rotary wing aircraft than fixed-wing types. To obtain the same amount of lift in low-density air requires higher blade pitch angles. This causes a less favourable lift/drag ratio and increases the danger of over-pitching in hovering or very slow flight. The decreased available engine power because of the low air density makes this danger even greater. In extreme conditions of high temperature, altitudes and humidity, it may be impossible to hover.

Takeoff and Landing Areas

When operating at near maximum payload takeoff limits, a considerable cleared area must be provided to establish translational flight. An area considered safe for takeoff under heavy load conditions should prove more than ample for landing.

Hovering and Ground Effect

Ground effect is reduced as rotor distance from the ground increases, and also when the nature of the ground surface is such that it tends to dissipate the downward flow, e.g., bushes, long grass, tall crops, etc. Care must be exercised when hovering over such areas.

Re-circulation has a detrimental effect on performance, as can occur when hovering in a small depression or a small forest clearing. A particularly dangerous situation occurs when hovering close to a tall obstruction such as a hangar wall, where re-circulation may be experienced on the side nearest the obstruction. The lift is reduced on that side, and the helicopter tends to tilt and move in the direction of the obstruction.

Operational Considerations

Mature crops may be beaten down by the rotor downwash at slower speeds, and care should be exercised to avoid hovering over such areas.

When operating into corners surrounded by high obstructions, consideration must be given to how the area may best be treated. Quick stops may be used, but again the effects of prolonged hovering must be kept in mind. Extra caution should be taken when flying around any high obstacle.

The ferry flight, field survey, entry and exit angles and swath run considerations covered in other sections apply equally well to helicopter operations. Swath turns are slightly different from fixed-wing aircraft and are covered in detail in the following sections, and apply to zero wind conditions.

Aircraft Dispersal Systems and Components

Requirements for Dispersal Systems

A dispersal system is the equipment that releases the pesticide and distributes it in a swath along the flight path. Two types exist — liquid and solid.

A number of materials are dispersed by aircraft on agricultural crops, rangelands, forests and other areas. Various forms of dry materials, such as granules and seeds, and various liquids sprayed with a wide range of particle sizes are applied by aircraft.

An important consideration in selecting dispersal equipment is the total volume to be applied per unit area. The total volume affects the choice of application equipment such as pumps, transfer pipes, nozzle sizes (for liquids) and spreader size (for solids).

Dispersal systems must:

- be able to safely and accurately deposit material uniformly within the target area
- be accurately calibrated, with monitoring systems to ensure continuing accuracy
- have rapid and secure on/off controls
- have a rapid and reliable emergency dump (jettison) system
- be easy and safe to clean
- be easily convertible from one material to another.

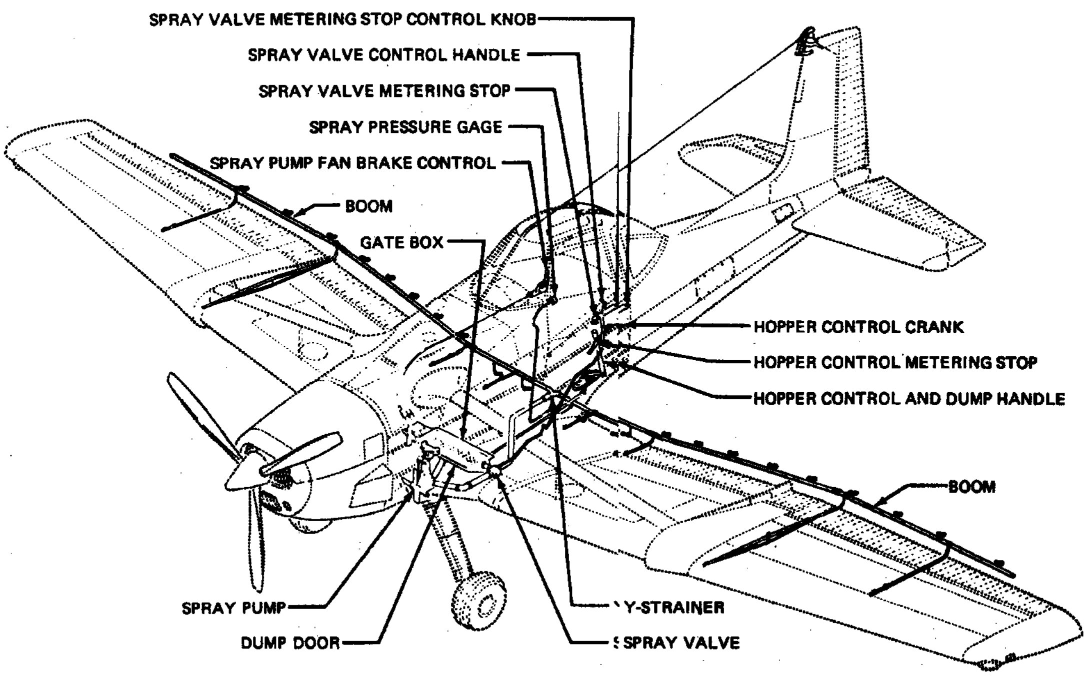
Liquid Dispersal System Components

Figure 7 shows a typical boom-nozzle liquid dispersal system. These can provide a wide range of application volumes and droplet sizes depending on the type of atomizer used.

The tank is fitted into a space forward of the pilot and aft of the engine. The emergency dump gate can be controlled by a lever located in the cockpit. The input from the tank to the pump is located in the bottom of the tank. The control valve, operated by a lever in the cockpit, directs the liquid back into the booms or, via a by-pass, back into the tank, keeping its contents thoroughly mixed by recirculation.

The spray pump is regulated by a brake in the cockpit. This enables the pilot to stop the action of the pump once the hopper is empty, preventing possible damage from overspeeding when the pump loading is removed.

Figure 7. Liquid Dispersal System (Strut-Mounted Pump)



Flow rate is adjusted from the cockpit by a lever connected to the control valve.

A cockpit mounted pressure gauge with a sensor, or a boom-mounted gauge, provides pressure readings.

It is becoming common to equip aircraft with flow meter systems (with a cockpit mounted display and a sensor placed just upstream of the T-junction) because they provide very accurate and continuous readouts of flow or application rates.

The major components of the liquid dispersal systems include:

- tanks
- spray pumps
- control valve
- flowmeters
- screens (filters)
- pipes and fittings
- pressure gauges
- spray booms
- spray atomizers

Tanks

- They must be liquid tight to prevent the escape of materials that might contaminate the cockpit area.

- They should be made of corrosion resistant materials, have suitable agitation for liquid loads so that they remain well mixed and have an accurate means of measuring quantity both on the ground and in the air.

- They should be well vented to eliminate any danger of collapse (a vacuum is formed as the material in the tank is released). Proper venting also provides a positive and constant pressure to ensure uniform flow rates.

- They are usually mounted forward of the pilot and over the centre of lift, so that changing weight does not greatly affect aircraft trim. Belly tanks are also positioned under the centre of lift for the same reason. For helicopters, where the centre of lift is directly under the main rotor, the tanks are split on either side of the engine frame.

Spray Pumps

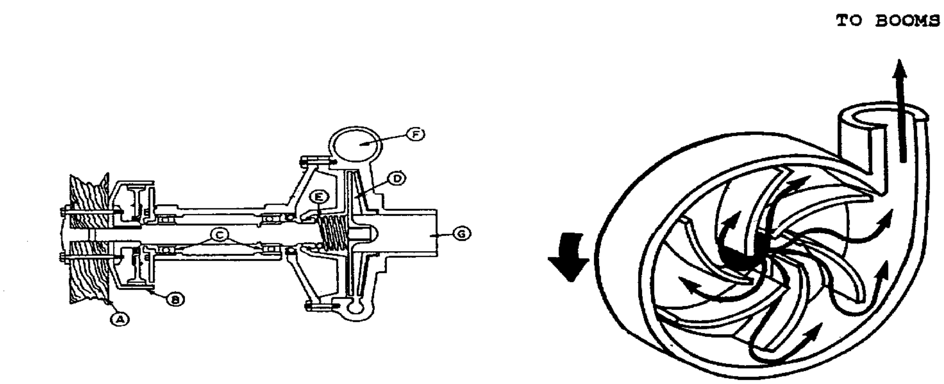
There are various types of spray pumps. The most common is the fan or the hydraulically driven centrifugal type for application rates of 10–100 L/ha (approximately 1–10 gal/ac) and upward. The pump must have sufficient output capacity to easily accommodate the required system flow rate, taking into account factors such as the maximum pressure limits of the flow line and nozzle requirements, and the reduced pressures that occur as the pump wears. They must also be placed lower than the bottom of the tank so that they will be self-priming.

Do not run the pump dry and always prime the pump before starting the pumping process.

Normal operating pressures should not exceed 415 kPa (60 psi), since higher pressures are less effective in achieving relatively uniform atomization. The lower normal operating pressure limit is 140 kPa (20 psi) to ensure proper nozzle spray patterns.

Figure 8 shows a cutaway view of a commonly used centrifugal pump. These characteristically give high volume at low pressure and are well suited for aircraft sprayer use. The pump bodies are aluminum with bronze or stainless steel impellers. The practical limitation of around 4000 rpm for an air-driven pump plus a pump size limitation places top pressure capability at around 415 kPa (60 psi).

Figure 8. Cutaway View of Centrifugal Pump



Other types of pumps, such as gear (Figure 9) used on rotary-wing aircraft and roller (Figure 10) pumps and variations of these, are used on aircraft either when higher pressures are needed (as for aerosol spraying) or the applied volume is greatly reduced, thus reducing pump discharge requirements. Such rotary pumps have to be more precisely made, wear more and in general do not fit aircraft requirements as well as the centrifugal type.

Figure 9. Gear Pump

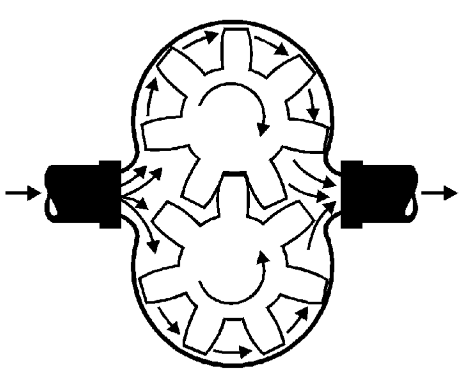
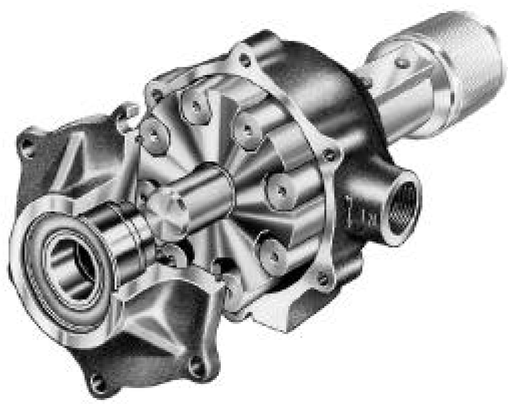


Figure 10. Roller Pump



Some centrifugal aircraft and transfer pumps with carbon-ceramic type mechanical seals have a tendency to leak after prolonged use. Leakage can be eliminated for longer periods using tungsten carbide, silicon carbide or carbide seals.

Power Sources for Pumps

A common power source for the spray pump is the fan drive, with the pump and fan placed between the main gear of an airplane.

Many have blade pitches either ground or air adjustable and incorporate a brake or feathering device to stop the pump when not in use, or in the event of failure of a shut-off valve. Propeller driven pumps are airspeed sensitive and provide accurate flows only at speeds and engine power setting used during calibration.

Although conventional fan driven pumps are highly reliable, their disadvantages are the high drag penalty they incur and their relatively low pumping efficiencies. For this reason, and also because of the need for better pressure control, operators often install a fan kit with an adjustable blade pitch to alter pump speed and flow rates.

With other systems, the spray pump is either driven directly from the hydraulic motor, or by a belt, chain or gear system. Hydraulic units have three main advantages over propeller driven systems. Because they are contained within the aircraft fuselage, they produce no drag. As well, the power produced can be regulated from the cockpit and is not dependent on airspeed. They are very powerful, which is very useful when heavy flow rates are required.

Helicopter sprayers often use a power take-off (PTO) drive unit or an electrical pump. Here, the main propulsion engine must have a suitable PTO point, capable of the horsepower required (10-15 h.p.). The pump is then either directly connected through a clutch to this take-off, or may be belt driven.

In general, PTO drives are very economical and practical and are used with increasing frequency on modern aircraft. However, they are not easily adaptable to older aircraft not designed for their use.

Control Valve

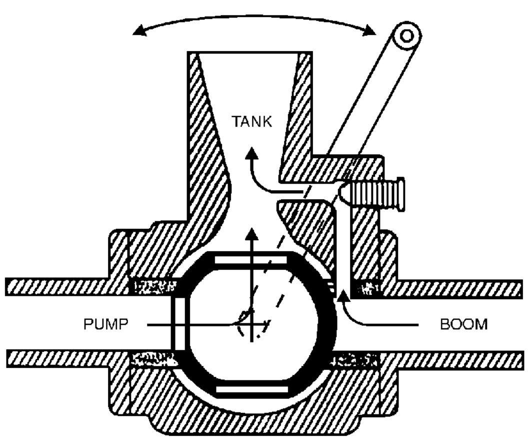
A typical control valve is made of stainless steel or aluminum, with plastic seats of polypropylene or Teflon to reduce wear and ensure a good seal. Figure 11 shows how the control valve functions. It is a three-way valve, with three flow-control positions.

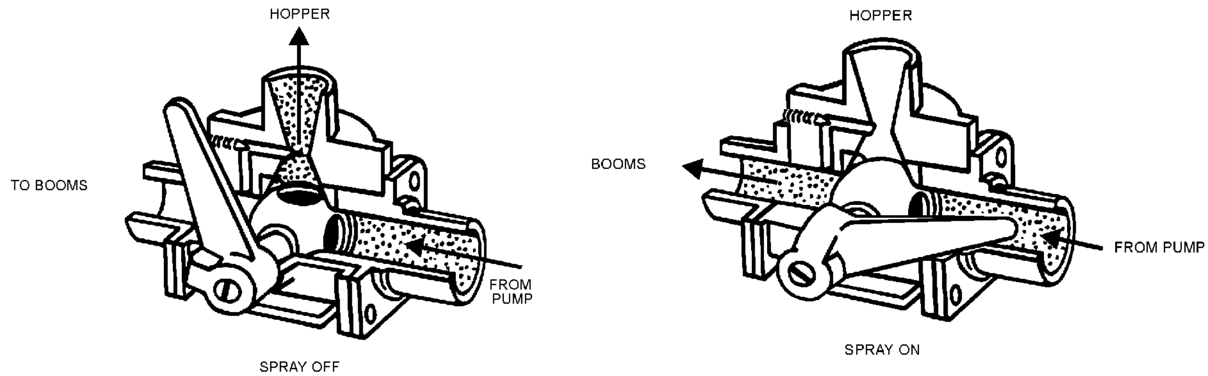
The “booms-on” position opens the line from the pump to the booms for spraying. The “booms-off” position closes this line and directs flow from the pump back into the tank. A third position, seldom used, connects the tank directly to the booms, useful for loading directly from the ends of the booms or for flushing the system.

An important feature of the valve unit is the **venturi throat** through which liquid passes in the “booms-off” position. Passing the liquid through this constricted passage causes a reduced pressure, resulting in a ‘suck-back’ from the booms. This ensures rapid and complete stoppage of spray when this position is selected. A small adjusting screw on the valve body regulates the amount of ‘suck-back’ possible.

This feature would empty the booms completely if the nozzles did not have one-way check valves to stop complete reversal of flow. Failure of a number of these valves could result in the boom emptying, which would delay the start of spraying in the “booms-on” position. For this reason it is important to monitor all nozzle units for correct operation and repair or change, if required.

Figure 11. Control Valve Operation





The most common failure with the valves usually occurs with the use of wettable powders, which cause abrasion and wear of closely machined parts. Daily flushing of the system and routine maintenance will prevent this.

Other control valves may be used, but the obvious advantages of the suck-back system have made this a universal installation on most aircraft sprayers.

Flowmeters

Electronic flow monitors such as those produced by Onboard Systems and Micronair involve a flowmeter sensing device (usually located between the ball (spray) valve and the booms), a computer and a visual display. The sensing device is a rotating paddle wheel or turbine that produces an electromagnetic pulse as it is turned by the fluid flowing by.

Display readouts on the monitor unit are selected as required. They include volume dispersed, volume remaining, dispersal rates, area covered and “booms-on” time. Once calibrated, flowmeters provide highly accurate readings that can facilitate aircraft calibration and can greatly increase application accuracy and consistency by allowing in-flight adjustments if conditions demand or allow it.

Refer to the equipment manufacturer’s directions for volumetrically calibrating flow meters with fluids other than water. Also, flow monitors that have interchangeable cartridges of different flow range sensitivities should have the correct cartridge or flow turbine installed.

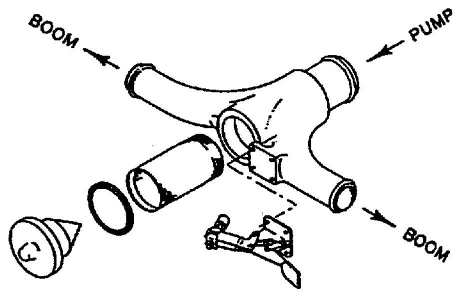
The accuracy of flowmeters is dependent not only on calibration but obviously on proper installation, operation and maintenance.

Screens (Filters)

Good filtration prevents pump damage and nozzle clogging. Screens should be easy to remove and clean, inspected regularly and positioned upstream of the pressure gauge to ensure accurate pressure measurement of the nozzles.

Screens or filters are usually located at three places in the system. The most important is the 'T' junction in Figure 1, shown in detail in Figure 12. This screen filters out particles that might plug the nozzles and check valves, and serves as a junction between the pump and the two boom sections.

Figure 12. 'T-junction' Boom Assembly



The screen (USA 25-100 mesh, or about 10-40 openings per centimetre) can be readily removed for cleaning, and the mesh size can be changed to suit the product being applied and the nozzle orifices. Smaller orifices require smaller mesh size for protection against plugging. It is desirable to keep the mesh size a fraction smaller than the nozzle orifice size.

Smaller screens are located in each nozzle just ahead of the orifice. These are the final filtering point before the liquid reaches the nozzle orifices. They should be cleaned regularly or whenever a clogged nozzle is observed. These screens are available in mesh sizes of 24, 50, 100 and 200 openings to the inch. Some are slotted for use with wettable powders. Use of improper strainer sizes can result in reduced nozzle flow rate and uneven application. The screen openings should be smaller than the nozzle orifice.

The third screen is contained in the bottom of the hopper at the opening to the pump. It is a large mesh screen designed to keep large pieces of material (rock, iron, etc.) from entering and damaging the pump. This typically is a 50-mesh screen.

Pipes and Fittings

All pipes and fittings must be corrosion resistant and leak-proof, and be large enough to permit appropriate volume flows with minimum resistance. They should be free of sharp bends to permit free flow and have beaded ends where connecting hoses are used. For safety reasons, all connection points should be double clamped.

The size of all flow lines should be sufficient to accommodate the highest anticipated flow rates. For high volume systems up to 570 L/min (150 gal/min), the input to the pump should be 6.3 cm (2.5 in.) in internal diameter and the discharge 5 cm (2 in.). For lower flow rates and smaller spray systems as with rotary-wing aircraft, sizes can be reduced.

The pipes and fittings must be inspected regularly and changed at any sign of deterioration.

Pressure Gauges

These gauges should be positioned where they can be read easily by the pilot. The sensor element should be located downstream of all line filters. Pressure gauges should be checked periodically for accuracy.

Spray Booms

Spray booms distribute the pesticide to the spray atomizers and facilitate proper spacing and orientation of the atomizers.

Booms must be made from sturdy, corrosion-resistant material such as stainless steel, brass or aluminum. They are either round or of a streamlined aerodynamic shape in cross section, with an internal diameter large enough to accommodate the overall flow rate. An internal diameter of 3.8–5.0 cm (1.5–2.0 in.) is sufficient for flows up to 570 L/min (150 gals U.S./min.). Streamlined booms have approximately 1/10 the drag of the same capacity round booms.

Screw taps for the nozzles are positioned along the boom, with enlarged threaded sections to give the nozzle mount extra strength. The usual spacing is 15–30 cm (6–12 in.). Because most wings slope upward from the fuselage to the tip, the booms must be mounted on the wing structure with special extensions to ensure all nozzles are parallel to the ground.

All boom attachment points to the aircraft must be secure. Couplings to the T-junction must be secure and leak-proof, and should be of the quick-disconnect type to allow for easy removal. The booms should also contain safety-wired quick-disconnect end caps to permit complete flushing of the entire boom assembly.

Spray Atomizers

Spray atomizers break the liquid spray into droplets as it is dispersed from the sprayer. The two main types of atomizers used in aerial systems are **hydraulic spray nozzles** and **rotary atomizers**. Manufacturers' charts are useful for selecting the size, number and orientation of atomizers for the appropriate droplet type and flow rate (i.e., litres/minute) to give total spray output (i.e., litres/ha) required. See the flow rate adjustment section for the formula for calculating required flow rate based on the required spray output. The total atomizers required will generally be 20–50 hydraulic nozzles or 6–10 rotary atomizers.

The selection of atomizer type, size, number and location on the spray boom are the most important decisions, affecting the number of droplets applied to a given area, the uniformity in size of the spray droplets, the coverage on the sprayed surface and the amount of spray drift.

Types of Spray Atomizers

Hydraulic Pressure Nozzles

These atomizers produce droplets when the spray is forced under pressure through a small orifice. Liquid is discharged through the nozzles in the form of very thin, unstable sheets moving at high speeds relative to the surrounding air. The difference in speeds causes a shearing effect between the sheet and the air, rapidly tearing the sheet into droplets of various sizes.

Figure 13 shows the five most commonly used hydraulic nozzle types. The **jet or solid stream** type is used for very coarse sprays (i.e., large droplets), such as for the phenoxy herbicides. Orifice size is designated by the Spraying Systems Co. in 64^{th}s of an inch. Thus, a D2 and a D3 are orifices having diameters of 2/64 and 3/64 of an inch (0.8 mm, 1.2 mm).

The **hollow cone nozzle** produces a circular hollow cone pattern with little or no spray in the centre. The nozzle has a whirlplate in back of the orifice that causes a spinning of the discharge liquid to produce a wide cone. The width is a function of the operating pressure and the size of the whirlplate in relation to the orifice. Smaller whirlplate numbers (i.e. 13, 23, 25, 45, 46 from the Spraying Systems Co.), indicate smaller whirl openings, which impart a greater spin to the spray, producing a wider cone angle and a finer spray when compared with larger whirlplate selections. These nozzles are common in herbicide work.

The spring-loaded diaphragm check valve (Figure 14) on the hollow cone nozzle gives positive shut-off control of the spray in conjunction with the boom suck-back system. The spring pressure of 20–55 kPa (3–8 psi) keeps the check valve closed in the “booms-off” position, when the control valve is closed and there is no high-pressure liquid in the booms. When “booms-on” is selected, liquid pressurized by the pump enters the booms, lifts the diaphragm, and passes the screen and travels out the whirlplate and nozzle orifice.

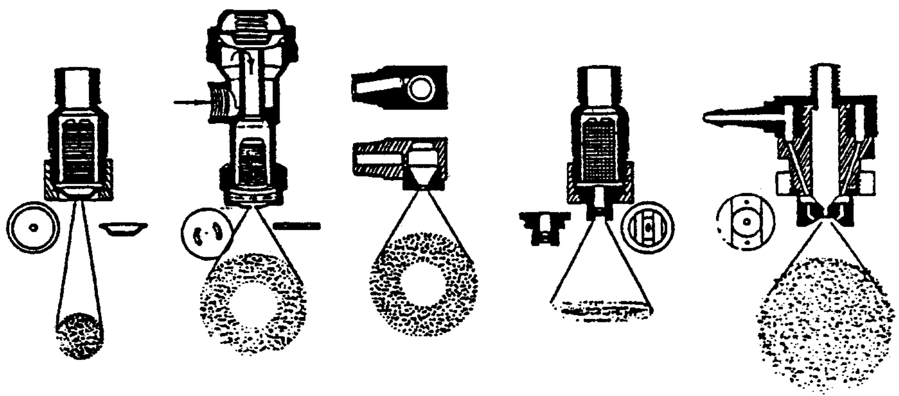
In addition, there are the **disc nozzles**, which use only the orifice in the nozzle body, producing a solid stream of liquid that breaks up in the wind shear. The **raindrop nozzle** is a disc core nozzle with an added swirl chamber to reduce small driftable droplets in the spray. These nozzles are used primarily with insecticides and fungicides.

The **non-clog nozzle** (**side-entrance hollow cone**) has an orifice that is much longer than that of the hollow cone type with whirlplate. The liquid enters the nozzle at 90 degrees to the interior wall, imparting a spin to the discharged liquid. This nozzle is not as versatile as the hollow-cone type with whirlplate as far as drop size is concerned. As a result, it is not so widely used.

The **flat fan nozzle** is widely used on ground sprayers as well as for reduced-volume applications on aircraft. Generally, the pressure should be between 100 and 200 kPa (15 and 30 psi) and not exceeding 280 kPa (40 psi). The wider the angle, the finer the spray. Manufacturers designate flat fan nozzles by numbers, which indicate the spray angle in degrees and GPM (gallons per minute) discharge. For example, an 8004 flat fan nozzles is one that produces an 80 degree fan angle with a 0.4 gal/min (1.5 L/min); an 8005 produces an 80 degree fan with a 0.5 gal/min (1.9 L/min) discharge. The flat fan nozzle produces a flattened fan-shaped spray pattern and is used for herbicide work.

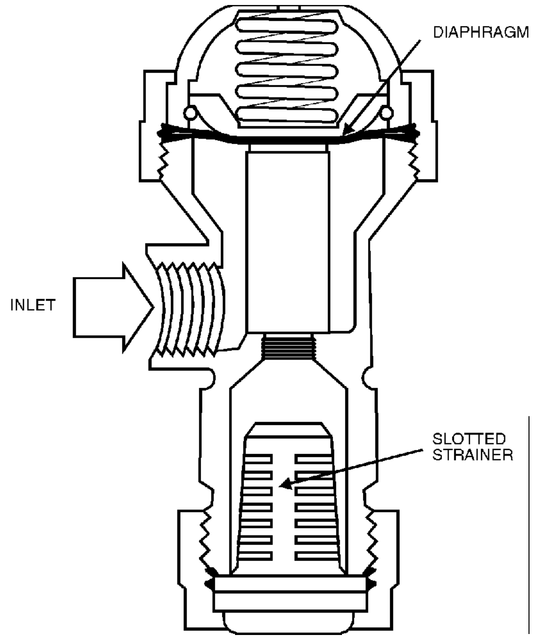
The **twin-fluid nozzle** is capable of very fine atomization to the point of producing true aerosols. Here, the liquid passes through the centre of the nozzle, and the air enters in two jets striking the liquid from both sides, producing a cone dispersion of very fine spray (down to 15-25 microns VMD). However, the orifice is so small that plugging of these fine nozzles becomes a serious problem.

Figure 13. Hydraulic Nozzle Types



Hydraulic-pressure nozzles. Left to right: (*a*) jet or solid stream for large-drop, low-drift spray; (*b*) the most commonly used hollow cone spray, showing whirlplate, which also uses a plate orifice similar to that of *a* (note also diaphragm type spring-loaded check valve); (*c*) side-entrance hollow cone nozzle; (*d*) fan type nozzle; (*e*) twin-fluid (air and liquid) nozzle used for producing aerosols.

Figure 14. Nozzle Construction



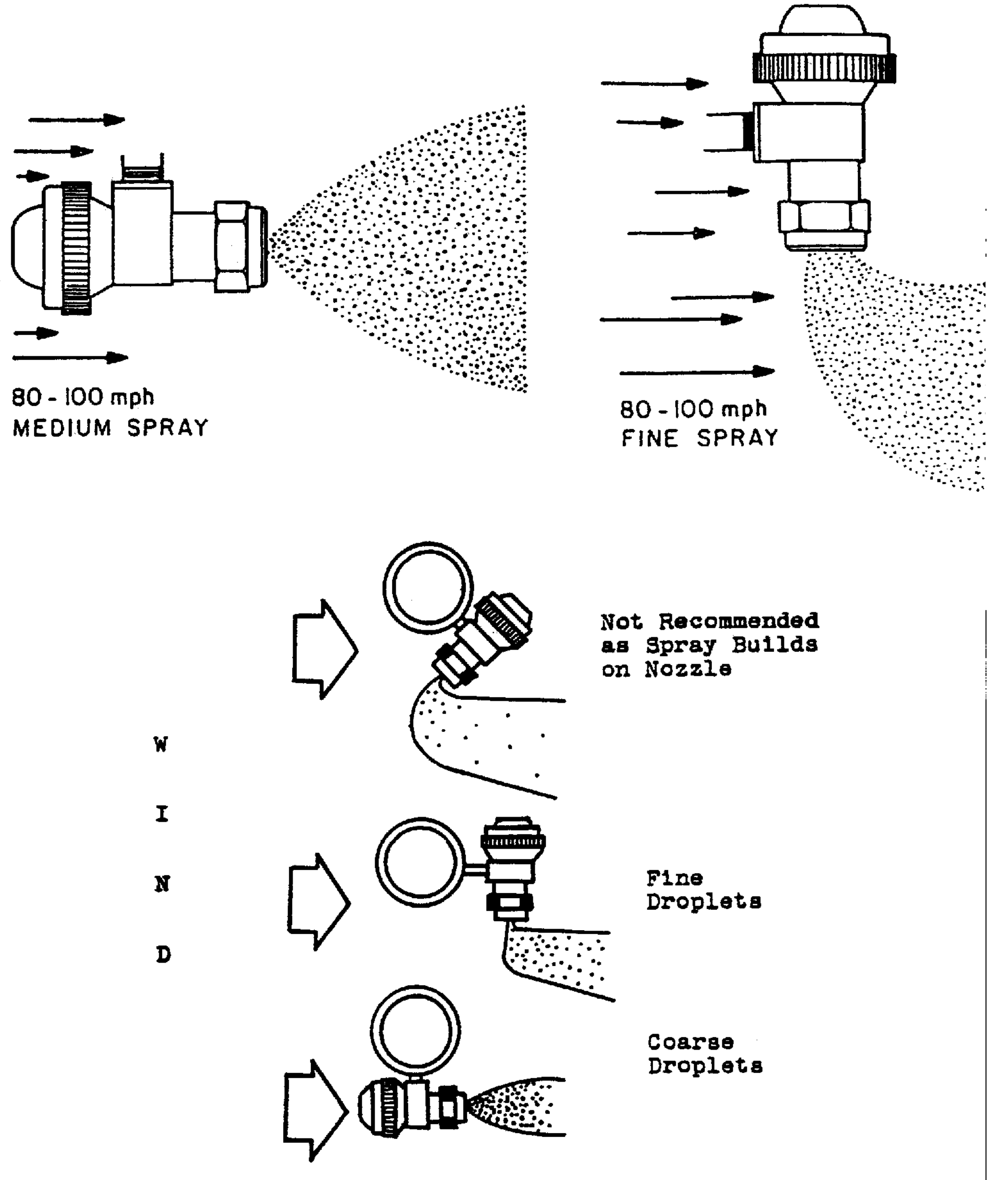
Droplet size for a given hydraulic nozzle design decreases with increased boom pressure and smaller orifice sizes. As well, rotating the nozzle orientation in relation to the slipstream (Figure 15) from rearward facing through 180 degrees to directly into the slipstream causes a continually decreasing droplet size.

Nozzle orifices must be checked regularly for wear and should be replaced when they produce a distorted spray pattern or exceed their original flow rate (as checked during calibration) by 15 percent. A visual check of nozzles in flight or during a ground run will often identify malfunctioning or worn units that need replacing.

Nozzle wear increases with more abrasive pesticide formulations, higher operating pressures and smaller orifice size. In general, the harder the nozzle material, the longer the nozzle will last. Brass is one of the softest nozzle materials; ceramic is one of the hardest. Other materials such as stainless steel and plastics fall between the two. Be aware that brass nozzles can wear so quickly that the flow rate increases by 10% after only 10 hours of operation with abrasive pesticides such as wettable powders.

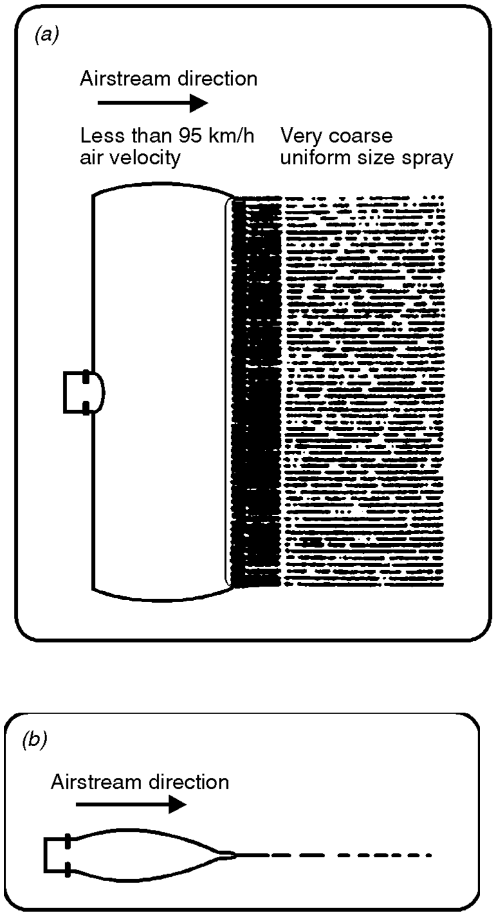
Manufacturers' charts provide the correct size and number of nozzles for the appropriate droplet size, angle of spray and total flow rate. Proper selection of nozzles is crucial to maximizing spray effectiveness. Select nozzle-types that also provide the correct flow rate and droplet size at a given pressure, with the droplet size selected to ensure adequate coverage while minimizing drift.

Figure 15. Nozzle Orientation and Droplet Size



The **Microfoil nozzle** (Figure 16) is another type of hydraulic nozzle used particularly on helicopters. They were developed to produce large droplets with relatively little drift potential. The nozzle produces droplets in the range of 800–1000 microns, provided the airspeed does not exceed 96 km/h (60 mph).

Figure 16. Microfoil Nozzle



(a) Microfoil nozzle.
(b) The nozzle from the side.

Rotary Atomizers

Many different types of rotary atomizers have been used (including spinning disks and brushes). Two commonly used today are the Micronair[1] (Figure 17) and the Beecomist[2]. While primarily used in ULV forestry insecticide operations, where fine droplets are required, rotary atomizers are also used for herbicide and fungicide applications.

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1 *Registered tradename of Micronair Limited*

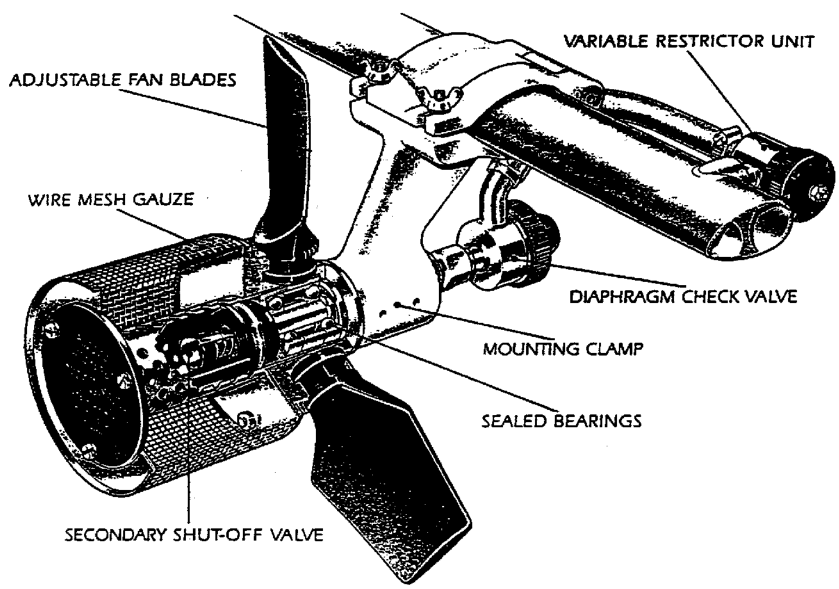
2 *Registered tradename of Beecomist Systems Inc.*

Both these atomizers consist of a wire mesh cylinder (cage) that spins at high rpm around a hollow central shaft. Spray droplets are formed when fluid dispersed from the central shaft shatters on the spinning wire mesh cylinder. Unlike hydraulic atomizers, boom pressure does not affect droplet size. Instead, the size of the droplets is related to the rotational speed of the wire mesh; the higher the speed, the smaller the drops. A distinct advantage of rotary atomizers over hydraulic nozzles is that they produce droplet sizes that fall into a narrow spectrum. However, care must be taken not to exceed recommended flow rates, since flooding the cages will produce inconsistent droplet sizes.

The Micronair atomizer is driven by airflow, consequently, *the droplet size depends on the angle of the adjustable fan blades and the air speed*. The low weight and drag of newer model Micronairs (i.e. AU5000, AU7000) enable them to be fitted directly onto a standard spray boom without any structural modifications, the usual setup containing from 6 to 12 units.

Beecomist atomizers are driven by either electric or hydraulic motors, thereby enabling the rpm to be adjusted as required. The rotational speed and droplet size is not affected by variations in airspeed. The pilot should be aware that the Beecomist units are relatively heavy compared with the Micronairs and also must ensure that the aircraft electrical system is not overburdened by the Beecomist units.

Figure 17. Micronair Atomizer



Advantages of Rotary Atomizers:

- ! the units produce a narrow droplet size spectrum, which is adjustable over a range of droplet sizes and flow rate settings (see Figure 36 later in this Chapter)
- ! fewer units to maintain compared to hydraulic nozzle set-ups

Disadvantages of Rotary Atomizers:

- high initial cost
- greatly increases in-flight drag
- higher maintenance
- increased drift

Solid Dispersal Systems

Granular dispersal system components include:

- hoppers
- spreaders

Hoppers

Hoppers are usually an integral part of the airframe. They must be dust tight to prevent escape of materials that might contaminate the cockpit area. With granular applications, an adjustable opening at the bottom of the hopper is required to allow the granular material to flow into the spreader. As well, a sloped wall design will ensure consistent flow rates.

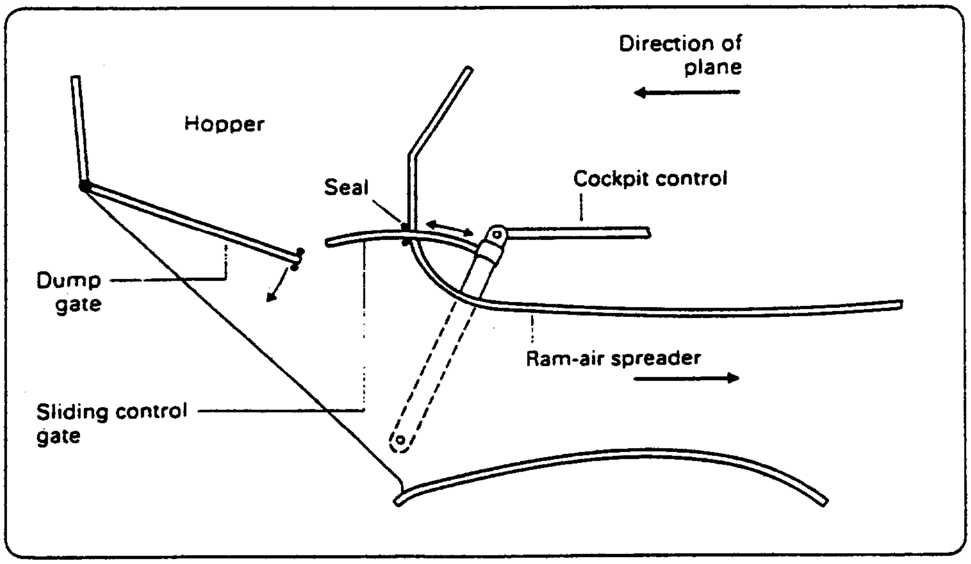
Spreaders for Fixed-wing Aircraft

The ram-air spreader is an example of a dry dispersal system used with fixed-wing aircraft. Opening the hopper gate allows material to fall into a channeled spreader attachment beneath the main gear. The airflow through the spreader dispenses the material, with adjustable vanes imparting a lateral spreading action for increased swath widths and adjustable deposit pattern.

The hopper gate meters the flow by the extent to which it is opened. It is also used to stop and start flow. Usually there is an adjustable stop located on the gate control in the cockpit, which permits setting the limit of the gate opening to a prescribed flow rate.

A metering gate (Figure 18) describing a large-radius arc covering maximum hopper gate extension must be incorporated, with slotted openings corresponding to the spreader vane positions. Each opening should be approximately 1.5 cm. This allows a very fine adjustment of flow rates over the entire range of the hopper gate movement. At lower rates, material may not disperse in a manner that provides appropriate coverage because granules do not flow freely. If low rates are required, the pilot should determine the lowest rate that can be applied effectively with the equipment.

Figure 18. Metering Gate for Ram-Air Spreader (*After*: FAO, 1974.)



The standard hopper vent may have to be modified to form a forward pointed airscoop at least 7.5 cm in diameter. This ensures an even pressure in the airtight hopper as load decreases with a resultant constant flow rate of materials. Modifying the vent in this way will increase the potential flow rate compared with a straight vent.

Spreaders for Rotary-wing Aircraft

Commonly used dry material dispersal systems for helicopters involve a rotating spinner, or rotating tubes or hoses, to throw the solids into a satisfactory swath. The rotating tube system is generally electrically driven and attached to or within the aircraft. Solids can also be dispersed from slung buckets, generally with a spinner powered by a small gasoline engine or hydraulics. Another design for granule dispersal can be attached to either saddle tanks, or slung buckets with divided hopper bottoms. A rotating drum metering assembly unit delivers a measured amount of product into a short boom supplied by a 225 kilometre/hour (kph) airstream. Uniform dispersal is accomplished by proper positioning of the discharge tubes and adjustment of deflector plates further out on the boom.

Navigation and Swath Guidance Systems

To provide accurate, uniform coverage, a pilot must have some means of swath guidance, so that all passes are parallel and with the correct lateral separation. The accuracy required varies according to the nature of the application. Granular materials or coarse sprays with relatively narrow, high-density swath patterns must be laid down very accurately for optimum results. ULV applications characteristically have a much broader swath width, and the need for accuracy is reduced.

Ideally, all swaths would be separated by a distance equal to the effective swath width. Narrower or wider separations would result in over-dosing or under-dosing, respectively. A number of methods can be used to achieve equally separated swaths in agricultural work.

Ground Features

For an experienced pilot, ground features such as trees, poles, large rocks, patches of bare ground and sloughs can provide surprisingly accurate swath guidance. The primary advantage in using natural markers is that their large size makes them easily visible, and the pilot is not dependant on either the arrival of flaggers or possible malfunction of an automatic flagger.

It must be stressed that, in situations where very precise swath guidance is required (desiccation, seeding, etc.), natural ground features should be used with great caution.

A single feature can be used for more than one swath. For example, if one swath is centred directly on a tree, the centreline for the adjacent swath would be one swath width to one side. Caution should be exercised when using a single natural marker for more than two swaths, since the spacing inevitably becomes narrower the further the distance from the marker.

If the flight path is parallel to the crop rows, the use of a single marker for each path will suffice. However, when working perpendicular to the rows, it will be necessary to choose at least two reference points to ensure the swath is laid down correctly.

Global Positioning Systems (GPS)

It is becoming the industry norm for aircraft involved in aerial application to be equipped with Global Positioning Systems (GPS). It is generally accepted that guidance provided by GPS is superior to other methods. The GPS receiver collects information from a constellation of satellites and, through the process of triangulation, the on-board computer calculates the aircraft position with an accuracy of less than one metre. The systems are flexible and can be used in several ways to guide spray applications. The pilot can have the spray block boundaries and all spray lines entered into memory prior to takeoff. Alternatively, the first line can be flown, e.g., on the edge of a field, and the system will build a block by generating a series of parallel lines at a given spacing. In any case, the block is flown by following directions given on a cockpit display.

Automatic Flagman

The ‘Automatic Flagman’ is a device mounted near the fuselage of an aircraft that ejects a paper streamer (flag) weighted at one end with a piece of cardboard. The release is triggered by a button on the control stick. (The entire flag is biodegradable and does not constitute an environmental hazard.) With practice, an automatic flagger can be a very accurate method of swath guidance.

The use of automatic flaggers presents several advantages. The pilot is not dependent on the presence or accuracy of human flaggers. It also eliminates any potential danger of pesticide contamination to human flaggers.

Human Markers (Flaggers)

In some jurisdictions flaggers are still an important part of agricultural operations. They ease the pilot's workload considerably and enhance program safety and efficiency.

Well trained flaggers can provide not only very accurate swath guidance to the pilot, but can be very helpful in:

- pointing out hazards or sensitive areas
- confirming the spray is correctly reaching the crop and watching for conditions conducive to drift
- providing a safety check of the area to ensure it is clear before spraying
- performing a valuable public relations function, since they are the crew members most likely to speak directly to the owner or bystanders
- providing assistance to the pilot in the case of an accident.

Flaggers must be highly visible to the pilot. Wearing high-gloss white coveralls (the disposable type now available are ideal for this) or carrying a large flag on the end of a pole is usually sufficient. Waving the flag or arms above the head greatly assists the pilot in first acquiring the flagger's position when lining up.

The flagger's first position should be one and a half swath widths in from the field boundary, indicating the centre of the second swath (the field boundaries of course provide an accurate reference for the first pass). On each successive pass, flaggers move into wind a distance equal to the effective swath width.

It is imperative that flaggers can mark off distances accurately. Accurate pacing (where a certain number of steps represents a swath width) takes considerable experience before it becomes consistent. The use of a measured rope in the field will provide very accurate separations but can be quite cumbersome. As well, 'stepping off' the distance may prove difficult in rough terrain or when movement around trees or other obstacles is required.

Since the length of stride varies between individuals, each flagger should check the number of strides required for a particular swath width against a measured distance. This is particularly important when inexperienced flaggers are used.

All-terrain-vehicles or small motorcycles can be used to provide accurate marking. They also provide the flagger with high mobility compared with marking on foot. A simple means of establishing the proper swath distance is to mark a reference position on the front wheel with white spray paint. The number of revolutions required for one swath width can then be checked against a measured distance.

Other Types of Positioning Systems

Other types of flagging or positioning systems include:

- Pointer Aircraft - an aircraft with an onboard navigator leads a team of spray aircraft down successive parallel spray lines (common in forestry work).

- Spotter Aircraft - an aircraft (usually helicopter) is positioned at one end of the plot or the centre of a large treatment block. A navigator on the spotter aircraft directs the applicator aircraft onto flight lines and signals for booms on or off.

- Electronic Flagman - involves an electronic triangulation system with ground transponders and a cockpit display and provides a parallel track centreline guidance.

- Smoke Generator - involves oil injected into the engine exhaust manifold, which produces a thick smoke allowing the pilot to mark the line of flight with existing ground features and also provides an indication of existing wind conditions.

- Balloon Markers - ground teams position balloons to indicate swath centre lines and area boundaries (common in forestry work).

Review Questions - Application Systems

Aircraft

1. Name an advantage of helicopters over fixed wing aircraft in their distribution of spray.

Aircraft Dispersal Systems and Components

1. A dispersal system is the equipment that releases the pesticide and distributes it in a swath along the flight path.

   True False

2. A dispersal system must be accurately calibrated at the beginning of an operation and should not require monitoring from that time on.

   True False

3. Hoppers and tanks must be well ventilated to eliminate the possibility of collapse.

   True False

4. Flow meter systems should have a sensor placed upstream of the control valve.

   True False

5. Check valves in the nozzles shut-off the release of spray droplets when the boom pressure drops.

   True False

6. The most important filter is at the "T" junction between the pump and the two boom sections.

   True False

7. Nozzle screens should have a smaller mesh size than inline screens.

   True False

8. A boom internal diameter of 3.8–5.0 cm is sufficient for a flow rate of 190 litres per minute.

   True False

9. The input pipe to the pump should be 6.3 cm (2.5 in. I.D.) and the discharge pipe should be 5 cm (2 in. I.D.) for high volume systems up to 570 L/min (150 gal/min).

True False

10. Flow meters are calibrated by the manufacturer.

True False

11. The pump should be placed lower than the bottom of the tank.

True False

12. The operating pressure should not exceed 60 psi with a normal lower pressure of 20 psi.

True False

13. The propeller drive pump has the disadvantage of high drag.

True False

14. Hydraulic spray nozzles cannot be considered atomizers because they produce relatively large droplets.

True False

15. Droplet size for hydraulic nozzles decreases with increased boom pressure and smaller nozzle orifice sizes.

True False

16. Brass nozzles are less susceptible to wear from abrasion by wettable powder formulations compared with plastic nozzles.

True False

17. Droplet size produced by a rotary atomizer system is not affected by boom pressure.

True False

18. The size of spray droplets decreases as the rotational speed of rotary atomizers decreases.

True False

19. With fixed-wing solid dispersal systems, airflow (dependent on airspeed) through the spreader dispenses the material.

True False

Navigation and Swath Guidance Systems

1. Natural features such as trees and large rocks can provide accurate swath guidance.

True False

2. An automatic flagman eliminates any danger of pesticide contamination to human flaggers.

True False

3. Human flaggers should move downwind on each successive pass of the aircraft when a field is sprayed.

True False

4. Human flaggers should be responsible for checking that the spray correctly reached the crop and also for the safety of the pilot and bystanders.

True False

5. Since accuracy in marking off distances is imperative, flaggers should be well trained with equipment that can reduce human error.

True False

Section 2 — Application Procedures

Goals of this Section

When you have completed this section, you should be able to:

describe appropriate flying procedures for aerial application

describe the factors affecting swath characteristics

describe ways liquid and granular swath characteristics can be determined.

Introduction

In this section, you will look at application procedures used to apply pesticides effectively. As well, all aerial applicators should have an understanding of the factors that can affect the swath and therefore the uniformity of application. You will also be introduced in this chapter to ways to determine swath characteristics.

General Considerations

The following is an outline of guidelines and requirements for undertaking daily spray applications.

First Flight of The Day Requirements

! A thorough walk-around is mandatory for first flight of the day.

! Use a light load on first takeoff, particularly if a new strip is being used.

! Start the aircraft in plenty of time to permit proper warm-up, especially in cold weather.

! Fully brief the mixer/loader on the day's operations.

Staying Organized

! Carry at least two work orders whenever possible in the event that conditions do not allow application at the first planned area.

! Develop "go – no go" standards to fit the operation, considering:
- weather
- proximity of sensitive areas
- safety hazards
- limitations of personnel (i.e., fatigue, experience level, etc.)

- Forestry applications may require a pre-application flight over the area to be treated.

- Do not begin or continue an application if there is any doubt about the proper area or effectiveness of the application.

- Develop direct, standardized communications between all personnel (both office and field staff). It is particularly important that the pilot or ground crew supervisor is continually aware of any changes (weather, work orders, etc.) that may jeopardize the safety or effectiveness of the application.

- At the end of a day's operations, ensure all materials and equipment are cleaned, available and serviceable for the next day's operations.

Requirements Enroute

- Mentally note local landmarks to expedite return to the treatment area.

- Avoid populated areas.

- Fly at least 500 feet (150 metres) above all obstacles.

- Use the time enroute to check proper aircraft flight operation.

Requirements Upon Arrival at the Spray Area

- Verify correct area.

- Check for susceptible neighbouring crops.

- Check for hazards and ensure that the spray area is clear of all unauthorized people, traffic, livestock, wildlife, etc., confirming with ground personnel whenever possible.

- Check engine instruments before beginning spray runs.

Guidelines for Working a Field

- Work with a cross wind whenever possible, moving successively upwind on each swath to avoid flying through suspended spray droplets.

- Fly parallel to crop rows if at all possible.

- Exercise caution when flying into the sun.

- Continually verify that output corresponds to area covered.

Requirements Upon Return to Loading Area

- Fly a consistent pattern, watching for other aircraft.

- With multi-aircraft operation, establish departure and arrival procedures and stick to them.

- For fixed-wing aircraft allow plenty of stopping distance when landing towards loading area. This is particularly important when landing downwind.

- Use safe taxi speeds, particularly in the loading area.

Guidelines for Takeoff and Landing Areas

- Ensure landing area and approach/departure areas are suitable.

- Use reduced loads until takeoff performance on strip is well established.

- Ensure mixing/loading equipment is well clear of takeoff/landing areas.

Requirements for Cleaning Application Equipment

- Rinse the equipment thoroughly by flushing clean water or diluent through the pump, boom and nozzles or granular spreader.

- Check for and replace worn parts after rinsing with water.

- Dispose of rinsate by following provincial regulations and directions on the label. Rinsing may not be required on a daily basis.

- Decontaminate the sprayer when changing from one type of pesticide to another. Decontamination procedures vary depending on the pesticide being used. Consult the label or the manufacturer's representative for specific recommendations.

Application Techniques

Application Patterns

Spraying a field can be compared to painting a wall; the majority of area is covered by long parallel strokes, overlapping slightly at the edges. The tricky areas such as borders and corners are trimmed with shorter strokes perpendicular to the rest.

Either **racetrack** or **shuttle** patterns (Figure 19 and Figure 20) are the most commonly used to apply successive swaths for uniform coverage of a treatment area. The first pass is along the downwind edge of the field, one-half swath in for a no-wind situation. The pilot lines up along the downwind edge of the field, dropping to the spray height and selecting "booms-on" for the first pass (Figure 21). Booms are shut off before the pull-up over the obstacles, leaving a narrow strip that is to be covered with runs parallel to the obstructions.

Figure 19. Racetrack Pattern

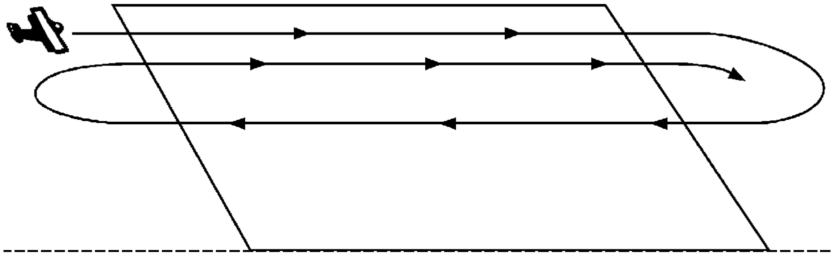


Figure 20. Shuttle Pattern

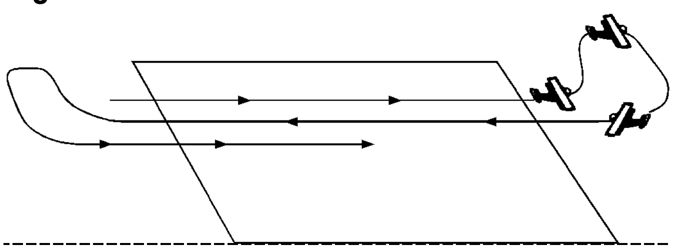
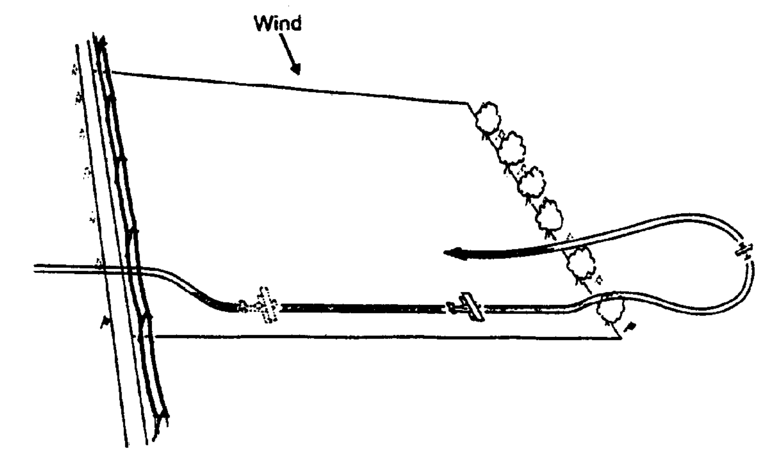


Figure 21. First Pass Along Downwind Edge of Field



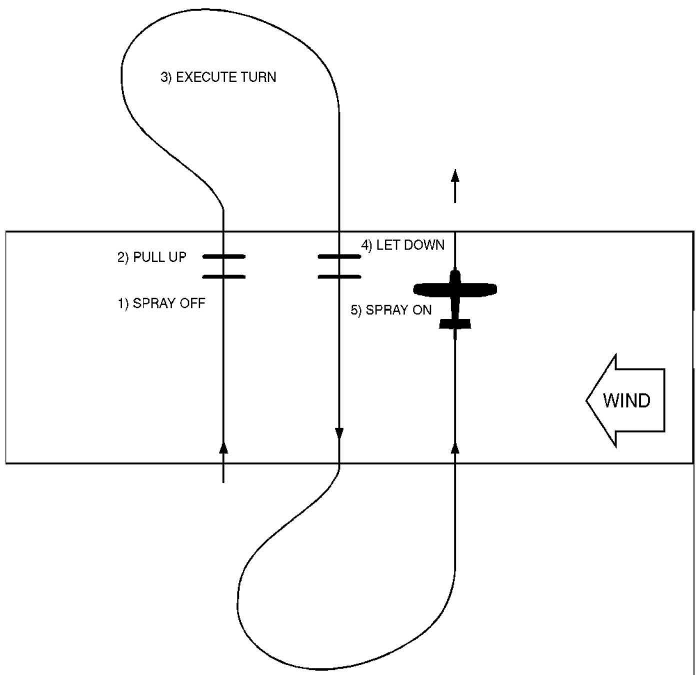
The racetrack pattern divides the field in half with progress as shown in the diagram. It is a good idea to drop a series of flags during the first centre field run, to define the limit of spraying as application progresses from the downwind edge. “Racetracking” is used for wide fields or for two separate areas where successive passes alternate from area to area (as in strip farming) where a 180 degree turn will comfortably align the aircraft for the next swath. It is less fatiguing than the shuttle pattern since there is no turn reversal, and the pilot can easily see the next swath throughout the broad turn.

With the shuttle pattern swaths are adjacent to each other and a procedure P-turn is used at each end. This pattern is used primarily for smaller width fields and in forestry work.

The Turnaround (Procedure Turn)

Figure 22 illustrates the standard turnaround used for reversing direction 180 degrees to begin the next swath and to clear any obstacles and to give the pilot sufficient altitude to orient to the next swath run. It is a critical manoeuvre that is executed repeatedly during aerial application. It needs to be flown carefully.

Figure 22. The Turnaround (Procedure Turn)



The pilot shuts off the booms just before a positive (but not abrupt) pullup to 50–100 feet. Once safely clear of all obstacles the nose is lowered, and the pilot turns downwind about 45 degrees away from the upcoming pass. This is to provide adequate lateral spacing for a turn onto the next swath.

The time spent in the turn for the next swath depends on the distance between swaths and the rate of turn that can be safely flown. Narrow swath widths, a heavily loaded aircraft or a very light wind extend the time in the turn for the upcoming swath.

Fixed-wing aircraft level off and reverse the turn 225 degrees to allow correct alignment and positioning the aircraft smoothly for reentry; rotary-wing aircraft modify this somewhat. If any abrupt manoeuvring is required, it is best to go around and try again. When a turn must be made upwind, extra time and space will be required to complete the turn safely.

The turnaround is not an 'airshow' manoeuvre. Wingovers, hammerhead turns and the like are very dangerous. Stalls in the procedure turn are common in accident reports as the result of several factors. The pull up and the turn put the aircraft in a low-speed, high-drag situation, with a decreasing margin of safety between safe flight and stall. There is also a tendency to look back during the first part of the turn, which may result in disorientation. Pilots may also hurry turns in an effort to decrease nonproductive turning time.

The goal is to fly a consistent turnaround, since this not only reduces pilot fatigue, but provides an opportunity to check hopper levels, aircraft and dispersal systems, and to confirm proper application rates once the turn is safely exercised. As well, whenever possible, the **pilot should avoid turns over residences, farm buildings, livestock, open water, pesticide free zones or other sensitive areas.**

Entry and Exit Angles

Entry and exit angles should be safe and consistent (equal) to ensure pilot safety and prevent uneven patterns at the ends of adjacent runs. With a heavily loaded aircraft, abrupt pull-ups or steep entries could stall the aircraft.

Trimming

If entry and exit angles have been consistent, there will be strips at both ends of the field at exit and entry that have not been treated. Trimming is simply a matter of flying at right angles to the regular runs to complete untreated areas at the entry and exit points, or when booms were off while flying over obstacles, or areas alongside sensitive zones. It is important to re-check the area for obstacles before trim runs, since the new direction of flight may mean obstacles that were not a hazard before can become serious concerns.

These untreated strips at each end of the field may also be done first, with the extent of trimming indicated by dropping flags. This assists estimating work done versus pesticide remaining when doing the rest of the field, as no allowance will have to be made for trimming. However, when trimming is difficult because of obstructions, it is better to leave these runs until the aircraft is lighter and more responsive. The pilot must take into account the amount of load required to complete trim runs.

Monitoring Application Rate

It is essential that the pilot continually monitor the rate at which the load is being applied, since serious consequences may result from over-application or under-application of the product. The pilot must know the amount of load that should be applied per swath run and continually verify that the correct rate is being applied.

Tracking Swaths

It is important to keep track of the number of passes made in comparison to the amount of pesticide dispersed. If the aircraft is not equipped with a built-in counter, a golfer's mechanical score counter can be taped to an easily accessible spot (i.e., spray valve control lever) to accomplish the same purpose.

For example, if the swath width is 18 metres and the field width is 800 metres, then 44 passes are required. After 11 passes, the field should be 1/4 done and 1/4 of the product used; after 22 passes, ½ done, etc. Using a racetrack pattern, starting the second swath down the centre of the field can greatly help in judging the area completed.

Flow monitors are ideal for monitoring application rates and can provide immediate verification that all is going according to plan. For example, using the formula:

$$\text{Hectares covered} = \frac{\text{Swath width (m)} \times \text{field length (m)}}{10\,000}$$

an 18-metre swath width on a 1600-metre field at 18.7 litres/hectare translates into 2.9 hectares covered and 54.2 litres dispersed per pass. The flowmeter can be set to indicate amount/pass or area/pass to confirm that the correct rate is being applied.

Without a flowmeter it may take several passes, particularly at low application rates, before verification of correct flow rates can be made by watching the drop in hopper lever.

The finish of a particular load should be anticipated and will be confirmed by a rapid drop on the pressure gauge.

Estimating Swath Width

Quite often, a pilot must work without ground flaggers to provide accurate swath spacing. While this may seem difficult at first, it quickly becomes second nature. If unfamiliar with the visual cues for a particular swath width, place flags at the appropriate distance apart on the landing area and fly over them at spray height until the proper visual clues are established.

Sloping Terrain

If confronted with steep terrain, it is best to work the area along the contour lines of the slopes. Alternatively, it may be necessary to make all passes downslope. A heavily loaded aircraft may not have sufficient power to maintain a safe airspeed when flying upslope.

While a very steep slope is obvious, a long, gradual upslope can be even more hazardous, since it is not easily recognized. Airspeed decay may go undetected to the point where the pilot is in serious trouble before recognizing the extent of the situation.

Obstructions

- Examine poles with power lines for guy wires and wires leading to adjacent buildings. Any building should be viewed as having a lead-in wire, whether or not it can actually be spotted.

- Check along power lines for branch wires; guy wires are commonly found on the opposite side. Where two lines meet at right angles, check for a diagonal wire directly connecting the two innermost poles on each line. Assume adjacent poles are connected even if the wire cannot be seen.

- When working over or near dugouts, sloughs or water-filled areas, be on the lookout for flocks of waterfowl. The impact of large birds can cause considerable damage to the aircraft or dispersal systems.

- **Be alert for hidden hazards**. Telephone pedestals servicing underground lines and deadheads extending from new brushpiles are just a few examples of hard to see hazards. Always be wary, even after you have been in the area for some time. Keep in mind that the hazards described by a farmer or flagger are viewed from a ground perspective; they may represent only part of the story.

- Communication and power lines are a prime hazard in agricultural work. Even though pilots may locate all wires before working a given field, it is very easy to lose track of these, or to lose sight of them against a dark field. Maintain continuous awareness at all times.

- There is considerable controversy over whether to underfly wires. In some cases (i.e., tall power transmission lines), it may actually be safer to underfly them. A heavily loaded aircraft could wind up in serious difficulty if the climb over wires is not initiated soon enough. However, it is usually safer to overfly wires.

- If you decide to underfly a wire, fly with reference to the ground, using peripheral vision to ensure wire clearance. Watching the wires could lead to inadvertent contact with the ground.

- Ensure there is plenty of clearance. If any doubt exists about safety, overfly and use trimming runs parallel to the wires to complete coverage. **Remember that wires sag**; while it may be safe to underfly near the support poles, it may be impossible at mid-span.

- Treat mid-field obstructions and treatment areas alongside sensitive areas as you would those at the end of a field, i.e., use trimming runs to cover areas that are missed during pull-up and let-down.

Landing

Establish a consistent pattern upon return to the airstrip and fly it accurately. As well as being an excellent exercise in good airmanship and flight safety, it means there will be no surprises on landing, i.e., landing long and giving the mixing crew some unwanted excitement. This is particularly important since the majority of landings are downwind towards the loading area, so that a quick turnaround and takeoff into wind will follow.

It is critical that the pilot be aware at all times of changes in wind speed and direction. With downwind landings, even a small increase in tailwind component can dramatically increase the landing roll. If there is any doubt about safety, overshoot and land into wind.

Formation Flying

Formation flying uses a lead aircraft and one or more wingmen flying with the lead as a reference, often with a pointer aircraft to direct the sprayer aircraft. It is used primarily in forestry work or for very large fields. **Close formation flying must be avoided**. Adequate manoeuvring space must be available for all aircraft.

Speed

Operational speeds should be constant and the same as used during calibration to ensure accurate and uniform coverage.

Height Estimation

An accurate and consistent altitude ensures proper swath width and minimizes drift. For agricultural operations a boom height above crops of 2–3 metres (8–10 feet) is typical. In forestry, the height above the canopy is typically 15–30 metres (50–100 feet).

Swath Characteristics

Uniformity

Effective aerial application not only depends on applying the correct volume of spray and pesticide rate per hectare, it depends also on the uniformity of the spray deposit across the entire swath.

Lack of uniformity of the deposit across the swath can result in a poor application with ineffective control or over-application, which may damage crops and waste pesticide. Therefore, it is important to understand the factors that influence uniform application rate.

Swath width is the width of the deposit area from one pass. Swath can be described in terms of the distribution pattern across the swath width and in terms of effective versus total swath width.

Types of Distribution Patterns

Distribution pattern refers to the variation in density of the droplets or granules deposited at each point across the swath width. In general, there are three overall distribution pattern classifications shown in Figure 23. In practice, actual measured deposit patterns will exhibit significant variation or irregularity within each classification.

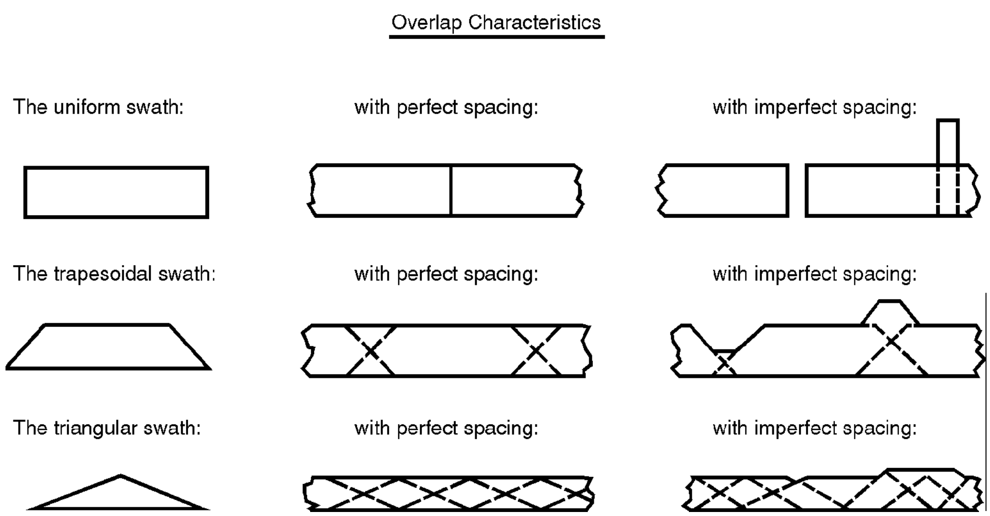
Trapezoidal: Aerial dispersal systems should produce a trapezoidal pattern, midway between the uniform and triangular patterns. Trapezoidal patterns are symmetrical i.e., relatively uniform across the centre, dropping off evenly at both ends. This pattern is least sensitive to errors in swath spacing and is most suitable for treatments requiring adjacent passes.

Uniform: A uniform swath is one in which the density of material is completely uniform across the entire swath. This pattern may seem desirable at first. However, it has very poor overlap characteristics.

Such patterns are excellent for one pass operations, but must be laid down precisely side by side for adjacent passes. Otherwise, areas in which there is overlap receive twice the intended amount and areas in which there is no overlap receive no deposit.

Triangular: A triangular density pattern across the swath has maximum density in the centre and a uniform decrease towards each end. This pattern will produce considerable variation in deposit across the swath if the swath spacing is not perfect. Triangular patterns are intermediate in sensitivity to errors in swath spacing.

Figure 23. Types of Distribution Patterns



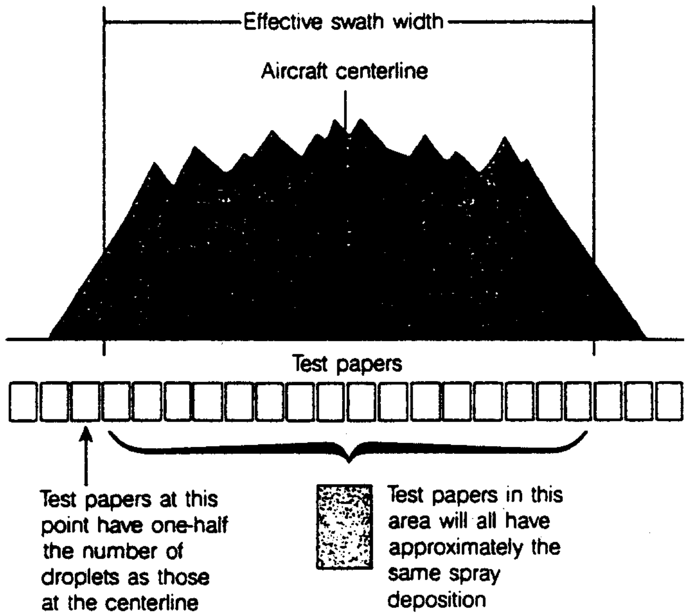
Total and Effective Swath Widths

The effective swath width must not be confused with total swath width. **Total swath width** is the maximum distance between the ends of the ground deposit pattern, regardless of the varying densities of material along the pattern.

Effective swath width is the distance between the two points on each end of the pattern where the material density has decreased to approximately half that at the centre. (Figure 24) Separating adjacent swath centrelines by the effective swath width ensures uniformity of spray deposit over the entire project area by overlapping the edges of the swaths.

In general, small fixed-wing aircraft (Thrush Commander and Grumman AgCat) have produced effective swaths ranging from 15 to 60 metres; small helicopters (Bell 47G) range from 15 to 30 metres and large helicopters (Bell 205) from 23 to 46 metres. However, this type of information must be verified for each spray aircraft and must be confirmed using pattern testing equipment and procedures. The effective swath width varies for different types of applications (i.e., forestry or agriculture) because of the difference in application height.

Figure 24. Ideal Deposition Pattern Within Swath



Factors Affecting Swath Characteristics

General

Many factors influence droplet or granule distribution patterns and swath width. They must be taken into account before application. These include:

- droplet size and behaviour
- boom pressure
- amount of material dispersed by granule spreaders
- airspeed
- groundspeed
- height of application
- type of aircraft

Droplet Size and Behaviour

Droplets move laterally because of the spanwise airflow from aircraft. The longer the droplet remains airborne, the more it will evaporate and the longer it will be affected by the spanwise airflow, hence, the greater will be the swath width. The larger (and heavier) the droplet, the faster the fall speed, and the less time these droplets will be affected by spanwise airflow. This is particularly significant where drift must be minimized because large droplets generally correspond to a decrease in swath width (See Figure 34 later in this Chapter).

Boom Pressure

At constant airspeed, the amount of material dispersed varies with boom pressure. Between 138 and 275 kPa is the normal working pressure range for hydraulic and rotary nozzles. Using higher boom pressures than during calibration will cause an excess of material to be deposited (spray deposit /unit area). Lower boom pressures will cause a decrease in spray output per unit area. **Maintain the same boom pressure used during calibration.**

Amount of Material Dispersed with Granule Spreaders

Spreaders impart a fanning pattern to the airflow, carrying dispersed material with it. The material moves aft and laterally, losing velocity until it eventually falls to the ground.
Higher airspeeds correspond to higher initial lateral velocities. Given a constant flow rate, higher air speeds will result in a wider swath width. With a given airspeed, increasing the application rate means the airflow has to carry an additional weight of material. This will decrease the initial lateral velocities with a corresponding decrease in swath width.

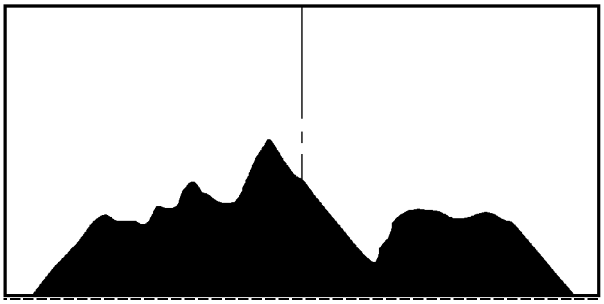
Airspeed

Higher than calibrated airspeeds for fixed-wing aircraft will cause a spike to appear on the centreline of distribution patterns (i.e., more material is deposited near the fuselage centreline). This is the result of increased tail loadings and a subsequent increased vortex, which may cause a visible “rooster tail” effect (Figure 25).

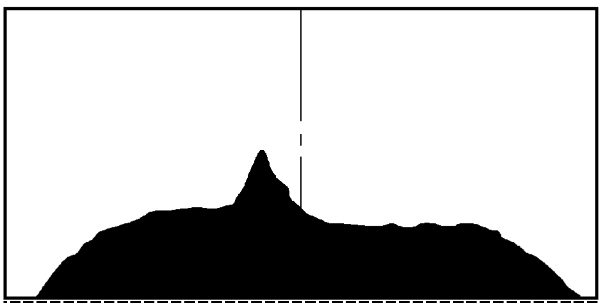
In general, speeds of 145–215 kph have produced acceptable **deposition** with small aircraft and 260–320 kph with large aircraft; however, this type of information must be determined for the aircraft in use.

Figure 25. Pattern Distortions

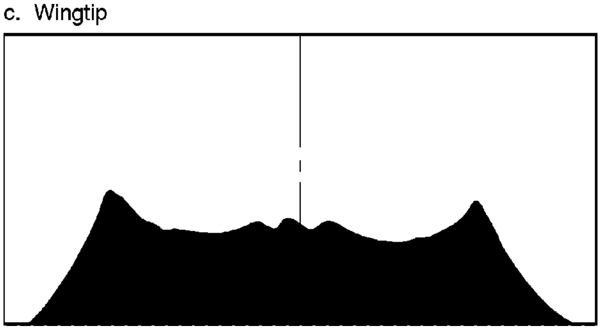
a. Propwash



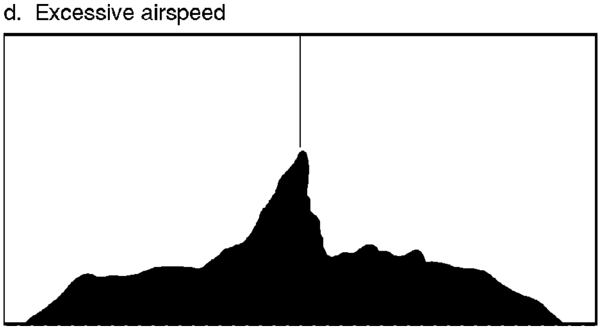
b. Over-compensation for propwash



c. Wingtip



d. Excessive airspeed



Fixed-wing Aircraft Characteristics

Aircraft airflow characteristics are influenced by wing tips, propellers, rotors, landing gear, spray boom and other equipment such as automatic flaggers. Each model has its own specific airflow patterns, which change significantly with changes in airspeed. Consequently, droplet distribution pattern testing should be done for individual aircraft and at the airspeed and height at which applications will be made.

Some of these airstream disruptions affect the distribution of droplets within the swath, but others, such as the action of wingtip vortices on smaller droplets, are a primary cause of drift from the target area.

Wingtip Vortices: Wingtip vortices originate behind the wings, slightly inboard from the wingtip. These vortices can cause uneven distribution and can carry small droplets aloft, where they have the potential to drift for long distances from the target area (Figure 25).

Material deposited on the outside edges of the swath frequently does not originate at the most outboard nozzles, but comes from nozzles further inboard. Material from nozzles that are located too far outboard can be caught up in wingtip vortices.

To prevent spray from being affected by these vortices, determine the furthest outboard hydraulic nozzle position that is contributing to the swath width by running swath checks, and turning off one nozzle at a time starting at the wing tip until the observed swath width begins to decrease. This position will not be usually more than three quarters of the wing span from the fuselage centre to the wing tip and no closer than one metre from the wing tip.

Placement of rotary atomizers is considerably less complex than the hydraulic types. Generally, four to six rotary atomizers are used in low volume and ultra low volume spraying, but more may be required if higher volumes are to be applied. Since fewer atomizers are involved, it is usually possible to place them out of the areas of turbulence, thus avoiding many of the problems encountered with hydraulic nozzle atomizers. In general, the outboard atomizer position is at 65–75% of the wing span or rotor diameter.

All atomizers should be adjusted to deliver the same volume and the same rotational speed. On larger aircraft (Thrush or Air Tractor), the inboard atomizers may be set at five degrees greater blade angle, which compensates for propeller turbulence and balances the atomizer RPM and the droplet size from all atomizers.

Propeller Wake: With uniformly spaced nozzles, propeller wake (propwash) causes pattern irregularities near the fuselage. Normally, less than the desired amount of material is deposited on the side of the downgoing blade and more on the opposite side. To compensate, locate more nozzles near the fuselage on the side of the downgoing blade. Run test swaths and adjust nozzle position accordingly until an even distribution pattern is achieved.

Aerodynamic Swirls: The landing gear, windmill pump and the flagging devices can also affect the distribution pattern. This can be avoided by using nozzle drops behind and slightly to each side of these areas of turbulence. The proper nozzle placement to counteract the turbulence caused by boom hangers and the spray booms themselves can be determined by pattern testing. In general, do not place nozzles directly behind or 3 cm to either side of a boom hangar.

Both round and airfoil shaped booms result in equally effective swath distribution patterns. Each type must be properly located on the trailing edge of the wing; each must have nozzles correctly located on the boom. Because round booms cause a great deal more drag than streamlined types, they are usually mounted approximately 10 cm directly behind the trailing edge of the wing. Streamlined booms are mounted about 10 cm behind and 10–15 cm below the trailing edge.

Nozzles should be attached to the rear and at least 3 cm away from the boom to remove them from the area of turbulence that surrounds the boom. If the nozzles are directly attached to the boom, spray material will build up on the nozzles and boom and will flow off as buildup occurs. This causes large variations in droplet size and distortions in the distribution pattern. The total number of nozzles will vary according to the requirements for the total volume of spray that must be delivered.

Remember that the primary factor determining the path of dispersed materials is the aerodynamic pattern produced by the aircraft and propeller/rotor wash. The larger (and heavier) the droplet size, the faster the fall rate, and the less it will be affected by this airflow.

Finer particles remain airborne longer and, consequently, will be more affected by airflow and wind. Generally, the smaller the droplet size, the wider the swath width, but also the higher the drift potential.

Using the coarsest spray possible that will allow effective coverage of the area being treated will reduce both airstream effects upon the pattern and minimize the drift potential.

Rotary-wing Aircraft Characteristics

The effect of turbulence generated by helicopters on swath characteristics is somewhat more complicated than that of fixed-wing aircraft.

Speed and Rotor Wake: At high forward speeds, spray can be lofted by the helicopter rotor wake in a pattern similar to that caused by wingtip vortices from a fixed-wing aircraft. At lower speeds, however, the high rotor wake downwash velocities may be used to advantage. The upwash velocities at the outer edges of the rotor wake may prove to be either an advantage or a disadvantage, depending upon several factors.

In a typical helicopter application, the rotor is located some distance from the boom. Consequently, some time is required for the rotor wake to affect the dispersed material. If the dispersed droplet size is large, and application is from a low altitude, the droplets may reach the target area before being affected by the rotor wash. This can be used to advantage with the application of volatile herbicides, where wake effects may cause drift problems.

On the other hand, during orchard spraying, it may be very desirable to have the droplets distributed into the wake, where agitation of the foliage by the spray-impregnated wake (as well as spray carried in the upwash at the wake edges) can result in good overall coverage, including the underside of leaves.

Nozzle Spacing: Evenly spaced hydraulic nozzles on a helicopter boom will not result in an even pattern. An effective layout will generally have closely spaced nozzles near the centreline, with spacing increased toward the centre of the boom semispan, and decreased again to the closest spacing toward the boom tip.

Swath testing for helicopters should be done in nearly calm wind conditions. This is also true for fixed-wing aircraft, but because of the relatively slow airspeeds used with helicopters the adverse effect of wind on accurate dispersal pattern testing is even greater.

Determining Swath Characteristics

Objectives

Swath characteristics for both liquid and granular applications are determined by flying the aircraft dispersing water or blank granules across some type of collecting/measuring apparatus or electronic analyzer placed perpendicular to its path. The density of deposited material is examined across the swath, and for liquids, the size of droplets is also determined. The examiner must account for the spread of the droplet with time on the collector to obtain a more accurate measure of droplet size. Analysis of the information allows determination of total and effective swath widths and proper equipment set-up.

Before the working season, applicators should determine and record swath characteristics and adjust the equipment configurations to give optimum swath patterns for each anticipated operation. Then when beginning each new operation during the application season, only the flow rate needs to be verified to ensure delivery of the required spray output.

Liquid Loads

An electronic analyzer provides the most accurate means of determining swath characteristics. Operators should make it a high priority to attend calibration clinics whenever they are held in the local area, since aircraft and equipment can be quickly checked and adjusted for optimum performance. Information on such clinics can be obtained from the Canadian Aerial Applicators Associations (CAAA).

If an electronic analyzer is unavailable, the spray pattern can be visually estimated with marker cards and dyes. Although it is more difficult to obtain detailed numerical results with this method (as from a spray analyzer), it will provide some indication of where there may be nozzle overloading or lack of coverage and other unsuitable characteristics of the swath.

Several types of deposit collectors have been used successfully to monitor spray deposit. These include white Kromekote cards, water-sensitive cards and oil sensitive cards.

A hard finish paper should be used if possible, since the droplets will spread less, giving some indication of droplet size. The papers should be approximately 5 × 5 cm, or you may use a continuous roll of paper, such as adding machine tape.

When using a dye, it is important not to alter the physical (viscosity) and chemical characteristics of the product and product mix. Before adding any additional material other than diluent, check with the manufacturer for compatibility. The following dyes have been used in aerial application for:

Water-based Product or Water diluted mixtures - food grade dyes including
- FD&C Red 40, 0.2% W/W
- FD&C Red 5, 0.1 to 0.5% W/W
- FD&C Blue 1, 0.1 to 0.25% W/W

Oil-based Products, undiluted
- 0.2 to 0.4% W/W D&C green 6
- 0.05 to 0.2% W/W FD&C red 17

Currently the only method for avoiding an incorrect estimate of spray droplet size is to read the spray cards immediately following applications. Sometimes the manufacturer can supply information on the change in droplet diameter on certain surfaces with time. For accurate assessment of droplet density, counting droplets can be accomplished using a lens with 5 to 10× magnification and with an internal one-centimetre square grid.

The pattern testing should be flown using the same flying techniques and equipment set-up that will be used in actual applications. As well, it is important to do the testing in a non-wind situation, since it will allow the applicator to check the pattern as influenced only by the equipment set-up, uncomplicated by other factors.

One approach is to place numbered cards in a straight line, fastened flat against the ground, spaced evenly one metre apart over a distance of 30 metres. If continuous paper is used, it should be secured to a lightweight board to keep the tape flat, and sectioned off at intervals of one metre, with the sections numbered. If there is a wind, the papers should be placed so the aircraft will fly into wind for the test.

The aircraft should be flown straight and level on a path centred on and perpendicular to the line of papers, using routine application airspeed, pressure and flying height above the canopy. Be sure the spray system is turned on 100 metres before reaching the papers, and left on the same distance after passing the papers to ensure a good pattern. Be sure the spray system has been operating long enough before starting the spray run to purge all air from the system. If using a dye mixture, run the system long enough to see the dye come out of the end nozzles before starting the test.

Following the spray run, gather the papers that have been numbered consecutively and place them next to each other in numerical order. Visually place them in order of highest pattern density to lowest. The highest density can be given a numerical value of 10, the lowest a value of 0 (many will of course have the same rating). If a continuous roll has been used, the tape can be cut into the marked sections, and the same procedure used as with individual cards.

Then, graph the results, with the horizontal axis being the cards in their respective positions (distance), and the vertical axis the assigned density values.

By visually checking the test papers as they are laid out side-by-side, you can assess where nozzles should be placed. While there may be some droplets on all of the papers, this part of the evaluation should concern only that area within the effective swath width, i.e., from the aircraft centreline outward to that point where is appears that one-half the average amount of spray is deposited. The ideal pattern within the swath is illustrated in Figure 24.

Move, add or plug nozzles as appropriate and retest, repeating until you achieve a satisfactory pattern of even distribution.

Granular Loads

The easiest method for verifying deposition rates for granular dispersal is to have a ground observer check the number of granules per unit area across the swath width. A standard-sized square wire form (30 × 30 cm) is ideal for this.

A second method involves placing shallow pans (e.g., tin pie plates) of known uniform size (area) across the flight path. Record either the weight of material or the number of granules trapped. The quantities are plotted on a graph to determine the pattern. The effective swath width is measured from where the density or weight of granules is half that at the centre of the swath. To verify the application rate (kg/ha) after finding the effective swath width:

- load a measured weight of material into the aircraft
- fly several passes while dispersing material, using either the timed interval or known distance methods to calculate area being covered
- return and find the weight of material remaining and consequently, the weight of material dispersed
- establish the weight/unit area dispersed from these figures

If changes are made to the application rate, the swath width will have to be re-measured.

Review Questions - Application Procedures

General Considerations and Techniques

1. The racetrack application pattern is commonly used on small treatment areas (fields).

   True False

2. The pilot must continually monitor the rate at which the load is being applied to ensure that over- or under-dosing does not occur.

   True False

3. The pilot should keep track of the number of swaths and the area treated to verify the volume applied and ultimately the application rate.

   True False

4. The procedure turn is a common cause of accidents.

   True False

5. Entry and exit angles should be safe and consistent to ensure pilot safety and proper coverage.

   True False

6. Trim runs should be the first operation of a field application if there are obstacles to contend with.

   True False

7. With sloping terrain and a heavily loaded aircraft the pilot should consider not flying upslope.

   True False

8. Pilots should establish a consistent pattern when landing and taking off but should be aware of changes in wind strength and direction.

   True False

9. Power lines present a dangerous situation and should never be underflown.

   True False

10. The pilot should carry at least two work orders in the event that conditions do not permit application at the first planned area.

   True False

11. For agricultural operations, a consistent boom height above the crop of 2–3 metres is typical.

   True False

12. If possible, turns during agricultural spraying should be done over houses or farm buildings to line up for the next swath.

   True False

13. While en route to a spray area, the pilot should mentally note landmarks to expedite return to the treatment area if required.

   True False

14. If involved with formation flying, one of the aircraft should be designated as the lead aircraft.

   True False

Swath Characteristics

1. The triangular distribution pattern is most suitable for treatments requiring adjacent passes.

   True False

2. Effective swath width is the area sprayed in which the droplets contain an effective dose.

   True False

3. Airspeeds used in calibration can be modified during the actual application if pressure is reduced.

   True False

4. Larger droplets generally result in a smaller swath width.

   True False

5. For granular applications, swath width decreases as the airspeed increases.

   True False

6. Swath characteristics vary with individual aircraft and droplet distribution patterns must be tested for each aircraft.

   True False

7. Material deposited on the outside edge of a swath originates from the wing tip area.

   True False

8. Swath width can be increased by extending the boom to wing tips.

   True False

9. Propeller wake requires more nozzles on the side of the downgoing blade.

   True False

10. Propwash has less effect on spray displacement if spray droplets are large.

    True False

11. Test swaths should be run to determine proper spacing of nozzles for an appropriate distribution pattern.

    True False

12. The helicopter rotor wake can cause a spray pattern similar to that created by wing tip vortices of fixed-wing aircraft.

    True False

13. The helicopter and the fixed-wing are similar in that nozzles should be fairly evenly spaced on the boom.

    True False

14. Before the application season, swath characteristics and the correct equipment configurations should be determined for all anticipated operations.

    True False

15. Swath characteristics are best tested under a no-wind situation.

    True False

Section 3 — Spray Characteristics

Goals of this Section

When you have completed this section, you should be able to:

‘ describe droplet size and the terms VMD and NMD

‘ describe the factors which influence droplet behaviour

‘ describe factors which may contribute to drift

‘ describe steps which can be taken to manage drift

Introduction

This section will look in detail at spray droplet behaviour. By having a good understanding of the factors that can affect spray droplets, you will be well informed on ways to manage drift.

Measuring Droplet Size

Perhaps the most important factor affecting the swath and ultimately the effectiveness of a liquid application is droplet size.

Sprays are characterized by their droplet size. Droplets are measured by their diameter in units called microns (1 micron (*m*m = 1/1000 mm). Table 2 provides categories of droplet sizes, with the associated diameters.

Table 2. Droplet Size Categories

Droplet Diameter (*m* m)	Droplet Size Category	Comparable Meteorological Phenomenon
600–1000	Very coarse, minimum drift agricultural sprays	moderate rain
400–600	Coarse spray	moderate rain
250–400	Medium agricultural sprays	light rain
100–250	Fine agricultural spray	drizzle
50–100	Coarse aerosol	mist
<50	Fine aerosol	fog

It is important to note that atomization of a unit volume of liquid can produce small droplets or large droplets. A small size results in a high number of droplets generated per unit volume. Increasing droplet size would mean a corresponding decrease in the numbers of droplets generated from the same unit volume. Table 3 shows the droplet sizes generated by a variety of nozzles.

Table 3. Aircraft Spray Droplet Size Range and Uses

Spray Descriptions and Atomizers	*Selected Atomizers	**Drop-Size Ranges in Micrometres (μm) VMD	***Percent Est. Deposit in 305 m	General Uses
Fine Sprays: Cone and fan nozzles, and rotary atomizers	80005 down D6-45 down (50–100 lbf/in.^{2})	50–300	40–80	Primarily for forest pesticides and large-area vector control with low dosage of low-toxicity and rapid-degradation chemicals. Also for agricultural insect pathogens.
Medium Sprays: Cone and fan nozzles, and rotary atomizers	8004 down D6-46 down (30–50 lbf/in.^{2})	300–400	70–90	Commonly used spray drop size for all low toxicity agricultural chemicals where good coverage is necessary.
Coarse Sprays: Cone and fan nozzles, and spray additives	8004 back D6-46 down (30–50 lbf/in.^{2})	400–600 with additives (up to 2000)	85–98	Recommended for toxic pesticides of restricted classification where thorough plant coverage is not essential.
Minimum-drift Sprays: Jet nozzles and spray additives	D4 to D8 down at less than 60 miles/hour (mph): back for over 60 mph (30–50 lbf/in.^{2})	800–1000 with additives	95–98	Recommended for all toxic, restricted herbicides, such as phenoxy acids, within the limitations of the growing season and nearness to susceptible crops.
Maximum-drift Control: Low-turbulence nozzles	Microfoil® at less than 60 mph airstream (Registered trademark of AmChem Corp., U.S.A.)	800–1000	99+	Actual drift tests show one quarter the drift residue levels at 152 m (500 ft) down-wind from the Microfoil® compared with D4-D8 jets used with restricted nonvolatile herbicides, phenoxy acids, and others in the area of susceptible crops, but subject to limitations of growing season and crops.

* Numbers refer to Spraying Systems Co. nozzles and “down” or “back” refer to orientation relative to the air stream on the aircraft boom.

** Drop size as determined with water-based sprays; oils would give smaller drops.

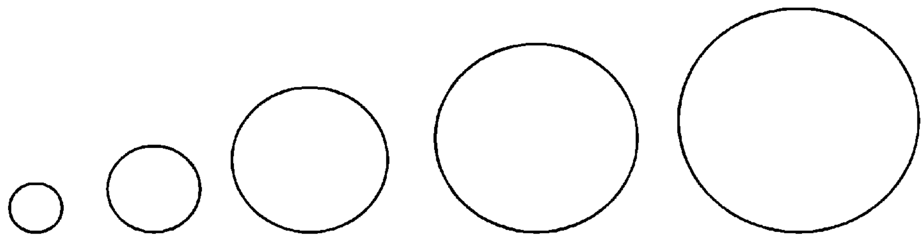
*** Deposit estimated in 305 m downwind. Weather conditions: wind velocity 5-8 kph; neutral temperature gradient. Material released under 3 m height.

The relationship between droplet size (diameter) and the volume of the droplet is extremely important because it is non-linear. Since droplets are spherical in shape, the relationship is given by the formula:

$$\text{Volume} = \pi \times \frac{\text{diameter}^3}{6}$$

Expressed simply, the amount of material in a droplet (volume) changes with the **<u>cube</u>** of the diameter. This means that a small change in diameter will result in a much larger change in volume, as illustrated in Figure 26.

Figure 26. Effect of Reduction in Droplet Size



Diameter (prior one)	100	200	300	400	500
Volume (cubic microns x 10^6)	.52	4.2	14.1	33.5	65.4
Diameter increase Factor	-	2x	3x	4x	5x
Volume increase Factor	-	8x	27x	64x	125x

Comparative Increases in Diameter and Volume for Varying Droplet Sizes
(all factors are relative to 100 micron droplet)

Figure 27 further illustrates the effect of reducing droplet size. As an example, a droplet that is 400 microns in diameter has a volume of:

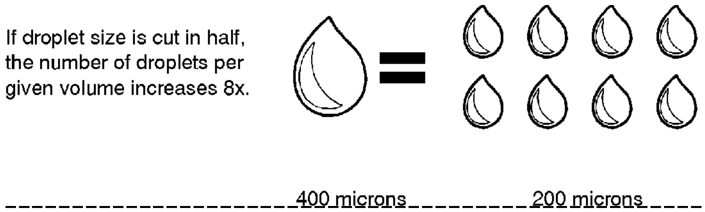
$$\pi \times \frac{400^3}{6} = 33.5 \times 10^6$$

If the applicator reduces the diameter of the droplets to 200 microns, the volume of each droplet is:

$$\pi \times \frac{200^3}{6} = 4.2 \times 10^6$$

By reducing the droplet size by half from 400 to 200 microns, the volume of each droplet is reduced to 1/8 of the original droplet volume. Thus for a given volume of spray material, one can produce *8 times more droplets by reducing the diameter of the droplets by half*, from 400 to 200 microns.

Figure 27. Effect of Reduction in Droplet Size



In actual usage, all atomizers produce sprays with a range of droplet sizes. Nozzle performance is characterized by two values: the most commonly quoted is the **Volume Median Diameter** (VMD) of the droplets, but a more meaningful description of the droplet spectrum should also include the **Number Median Diameter** (NMD).

If the volume contained in all the droplets is calculated by size, a size can be identified that divides the entire spray volume into two equal parts, i.e., half of the spray volume is composed of droplets smaller than this size and half of larger. This is the VMD (see Figure 28).

When the numbers of droplets in the spectrum are viewed in ascending order of size, a size can be identified that divides the total count into two parts containing equal numbers of droplets, i.e., there are as many droplets smaller than this size as there are larger. This is the NMD.

Using the VMD and NMD values together provides a more complete description of the droplet spectrum than when used separately. Figure 29 shows two patterns (A and B) with the same VMD's but with different NMD's.

Figure 28. Division of Spray to Show The Volume Median Diameter for Equivalent Spray Volumes

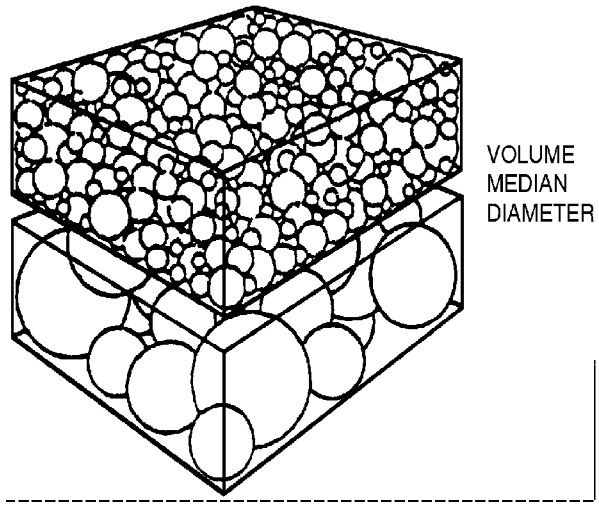
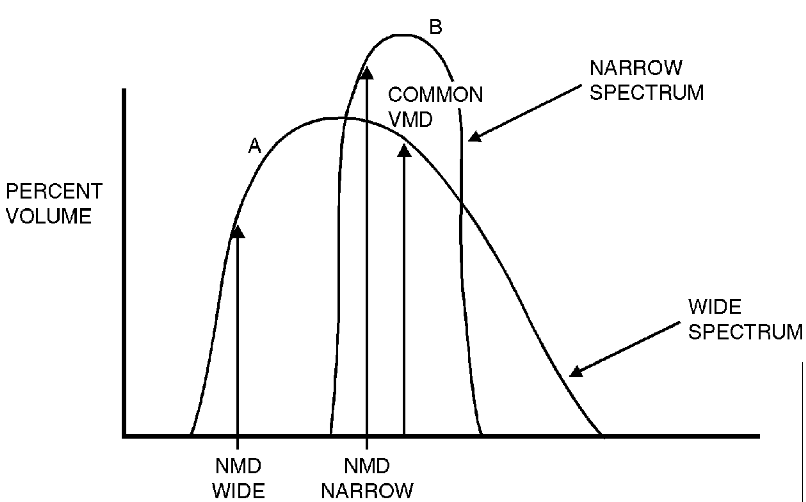


Figure 29. Comparison of Sprays With Common VMD's and Different NMD's

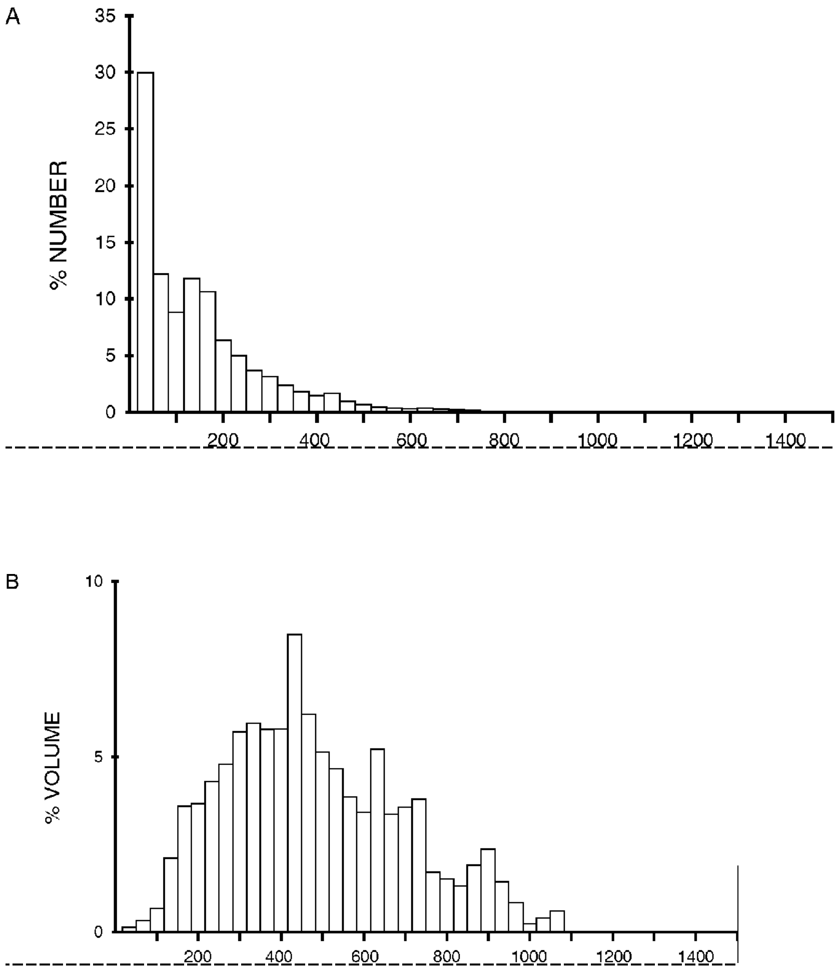


A comparison of droplet spectrum composition from spray with a common volume median but different number median diameter. The vmd alone does not describe the composition of the spectrum of these droplets without additional information such as the nmd.

Pattern A (characteristic of hydraulic nozzles) has a higher number of smaller droplets than pattern B (rotary atomizers), illustrating the more consistent droplet size produced with the latter.

Figure 30 illustrates the distribution of droplet numbers and volumes associated with the spectrum of a representative spray. Clearly, the smallest measured droplet size contains 30% of the total number of droplets, but these droplets contain only a tiny fraction of the total volume of the spray.

Figure 30. Droplet Size Distribution by (A) Number and (B) Volume



NOTE: In the following discussions, mention of changes in droplet size refers to changes in the VMD of the spray cloud.

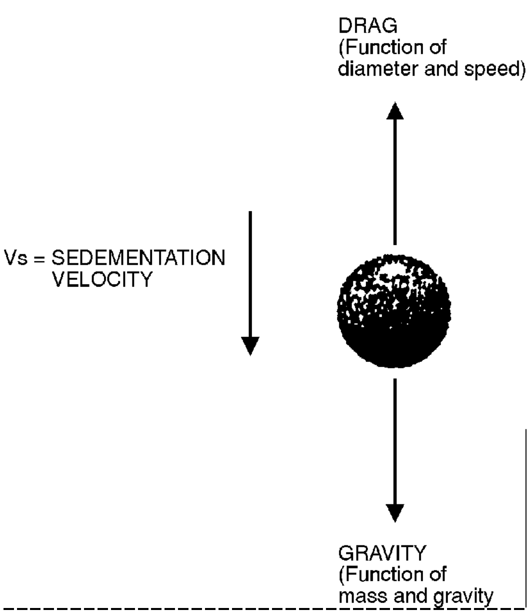
Significance of Droplet Size

Droplet size is a critical parameter that affects spray drift and efficacy in several ways. Under any given operating conditions all nozzles produce a range of droplet sizes—some much smaller and some much larger than the VMD. This is important because even if the bulk of the spray consists of large droplets of a size where wind, temperature and other influences are less of a factor, the many smaller droplets (or 'fines') may be greatly affected and constitute a potential drift hazard. Droplets of 100 microns or less in size are generally considered to constitute a high drift hazard. Figure 29 illustrates that although two sprays have the same VMD, the number of fines in "A" would be significantly greater than in "B".

The droplet size will also influence the coverage, the rate of settling, and the impact of wind. The greater the number of droplets, the wider and more thorough the **coverage** will be. The smaller size droplet spray will produce a greater number of droplets from a given spray volume. However, droplets of too small a size may not reach the target area because of the adverse effects of wind, temperature, etc.

On the other hand, overly large droplets carry a disproportionate amount of pesticide, with the result that some parts of the target will be over-dosed while others receive no coverage. An effective spray program must find a balance between the two extremes.

Figure 31. Forces Acting on a Falling Spray Droplet



Sedimentation is the settling of droplets. The maximum rate at which they fall (terminal velocity) is governed by the forces acting on the droplet, illustrated in Figure 31. Fall rates for different size droplets are shown in Figure 32. The slower terminal velocities of smaller droplets increases the time they can be influenced by wind. As well, their slower settling times mean that temperature and humidity effects may reduce their size even more through evaporation.

Figure 32. Fall Speeds of Different Size Droplets Under No-Wind Conditions

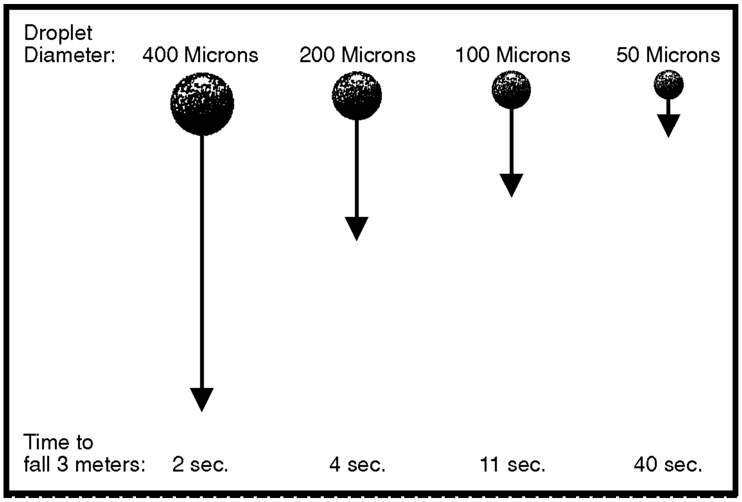


Figure 33 shows the relative drift in two different wind speeds of droplets of various sizes. It can be seen that decreasing the droplet size increases the amount of downwind displacement. This is particularly critical with very small droplets, since wind drift may take them beyond the target area.

Figure 33. Displacement of Different Size Droplets

The effect of windspeed on the displacement of different size droplets released from a height of 3 metres. Adapted from Bowers, W.: Reducing Drift of Spray Droplets, 1976.

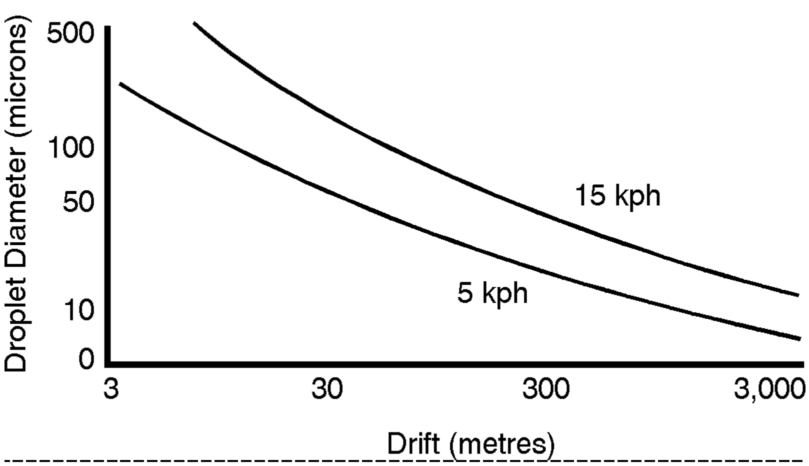
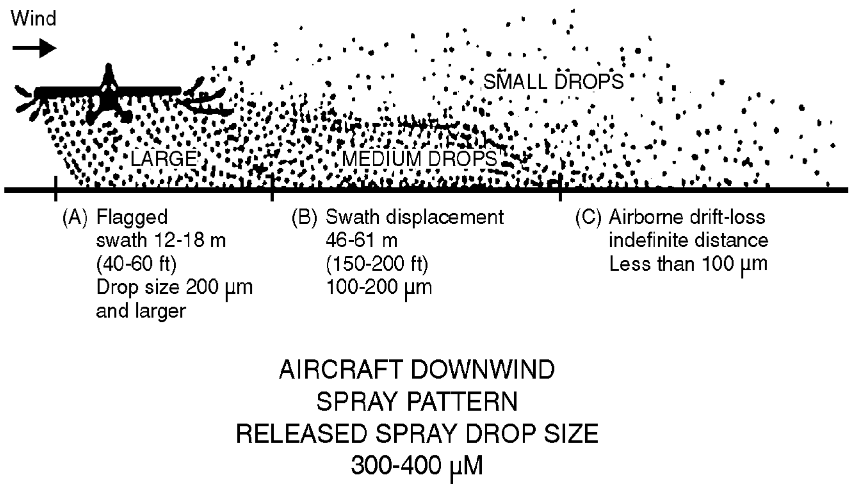


Figure 34 shows the downwind dispersal of various sized droplets, and separates swath displacement results from drift losses. Drift is defined as any dispersed material that lands elsewhere than in the intended application area. It is not to be confused with swath displacements that occur routinely as the result of crosswind effects. These are easily adjusted for by shifting the swath centreline an appropriate distance upwind.

Figure 34. Downwind Dispersal of Different Droplet Sizes
(Akesson and Yates 1984)



Factors Determining Droplet Size

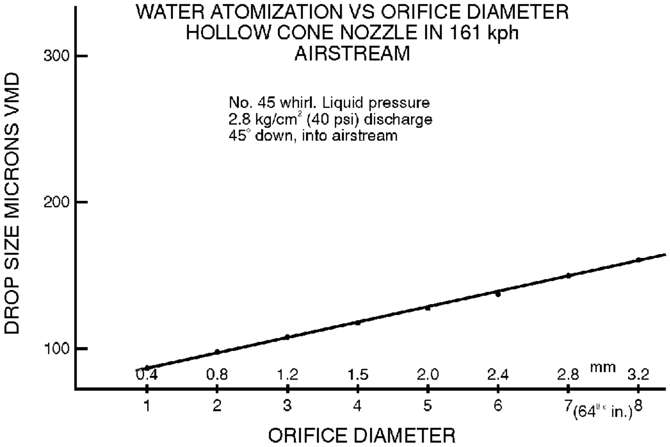
Droplet size is influenced by the following factors:

! nozzle selection
! nozzle orientation
! airspeed
! pressure
! evaporation
! formulation
! spray adjuvants
! nozzle placement on the boom

Nozzle Selection

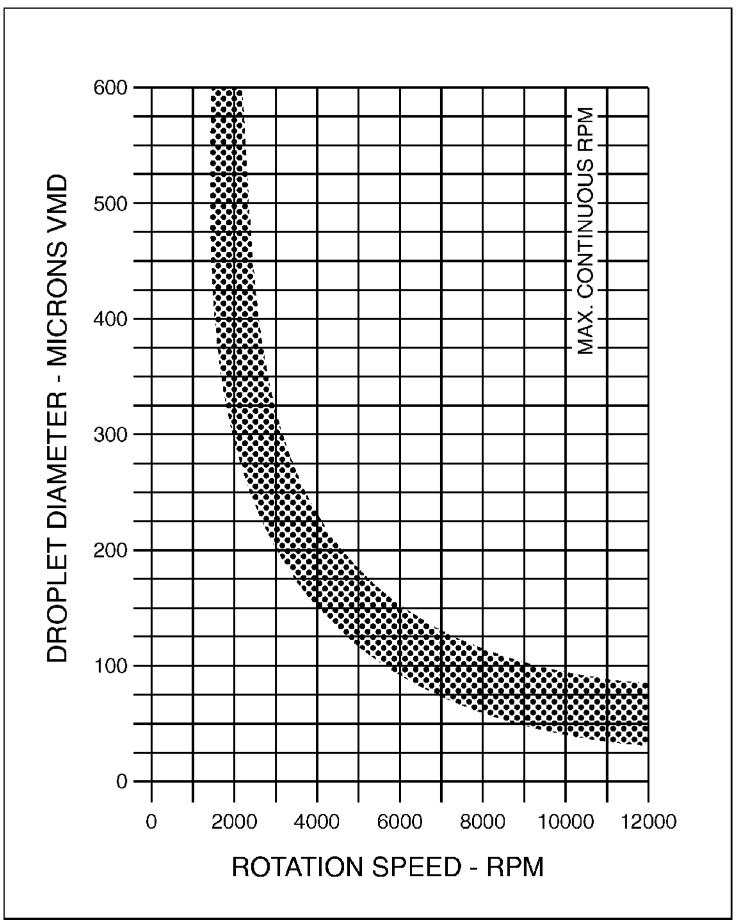
With hydraulic nozzles, droplet size decreases with decreasing orifice sizes. Figure 35 shows an example of how droplet size relates to changes in orifice selections.

Figure 35. Droplet Size vs. Orifice Diameter



Drop size versus nozzle orifice diameter for a hollow cone nozzle directed 135 degrees toward the airstream.

Figure 36. Droplet Size vs. RPM for Rotary Atomizer

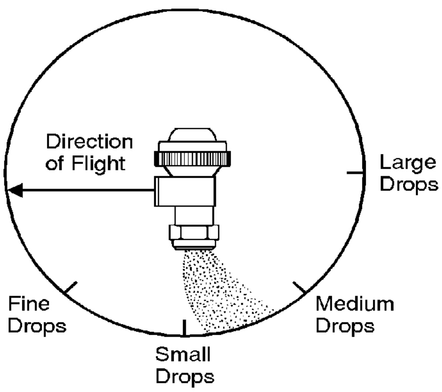


For rotary atomizers, droplet size is a function of the unit's rotational speed as seen in Figure 36.

Nozzle Orientation

For a hydraulic nozzle of a given size and type, droplet size can be adjusted most effectively by changing the angle of the nozzles into the airstream. Figure 37 shows the general effect of changing orientation.

Figure 37. Nozzle Orientation vs. Droplet Size



The greatest changes occur from 0 to 90 degrees, with very little change after 135 degrees. Pointing the nozzle directly into the airstream will not appreciably decrease droplet size further, *but may cause material to build up on the nozzle, causing flow problems and very uneven droplet size.*

Airspeed

For hydraulic nozzles, increasing airspeed increases the shearing effect of the airflow, with a subsequent decrease in droplet size (see Table 4).With airflow-driven rotary atomizers, increasing airspeed results in higher rotational speeds producing a smaller droplet size. Electrically powered rotary atomizers rotate independent of airspeed, and the impact of airspeed on droplet size is minimal.

Table 4. Airspeed vs. VMD. (Adapted from Isler, D.A. and J.B. Carlton. Effect of Mechanical Factors on Atomization of Oil-Base Aerial Sprays. Transactions of the ASAE 8(4): 590, 1965.)

Effect on airspeed on VMD of spray droplets

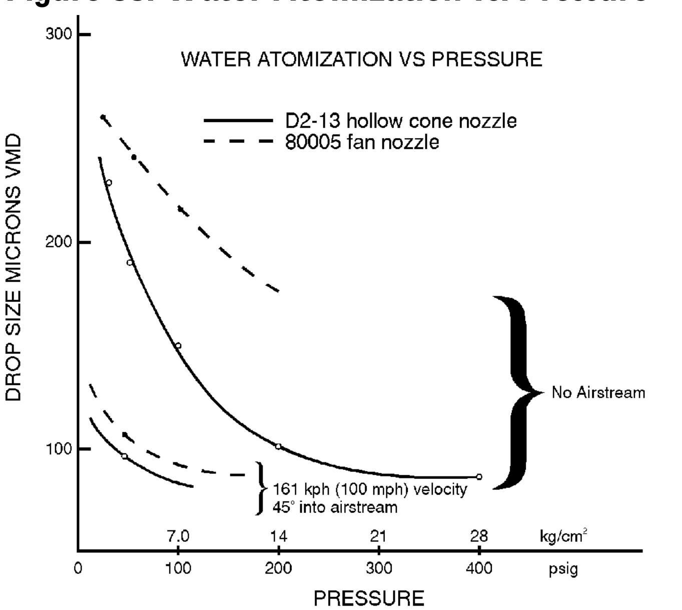
Airspeed (mph)	VMD (μm)
80	324
120	226
150	159
170	159
200	127
Nozzle	U50120 flat spray
Spray pressure	25 pounds per square inch
45 degree nozzle orientation	back and down 45° from horizontal

Pressure

Figure 38 shows the decreased droplet size resulting from increased pressures. As well, it illustrates the very significant reduction in VMD that occurs when airstream and nozzle orientation factors are introduced.

The flow from a nozzle is proportional to the square root of the pressure. Doubling the flow rate would require a fourfold increase in pressure. The most significant result would be the much greater production of number of fines, and a greater variation in overall droplet size, thus greatly increasing the drift potential.

Figure 38. Water Atomization vs. Pressure



Drop size versus liquid pressure for a hollow cone and a fan nozzle. Upper set in no airstream, lower set in 161 km/hr (100 mi/hr) airstream directed at 135 degrees (against) airstream.

Evaporation

Temperature and relative humidity influence how much a spray droplet will reduce in size on its way to the target area. The higher the temperature and/or the lower the relative humidity, the greater the effect of evaporation.

Table 5 shows the time and distance droplets of different sizes take to evaporate completely when sprayed into still air at 30 degrees centigrade and 50 percent relative humidity. As can be seen, very small droplets can disappear very quickly. This is because they fall much more slowly than large droplets and have much less volume to start with.

Table 5. Evaporation Effects

Drop Diameter (microns)	Lifetime (seconds)	Fall Distance During Lifetime (metres)
50	4	0.10
100	16	3
200	65	40

Droplet lifetime under conditions of 30 degrees Centigrade and 50 percent relative humidity. Adapted from Akesson, N.B. and W.E. Yates. **The Use of Aircraft in Agriculture**, Food and Agriculture Organization of the United Nations. Rome 1974.

In practical terms, this means that the smaller droplets or ‘fines’ may never reach the target area. They will evaporate completely and leave the pesticide as a crystal that will not impinge on foliage and may be carried far off the target. Temperature and relative humidity parameters established by the pesticide manufacturer must be adhered to in order to reduce this loss.

Formulations

Decreased droplet sizes through evaporation are greatly reduced through the use of non-volatile formulations with oils as the carrier in place of water. Since oil does not evaporate, the droplet size generated at the nozzle will be the same size when it reaches the target area regardless of temperature and relative humidity.

However, although non-volatile formulations stabilize droplet size so they are not reduced by evaporation, a significant number of fines (VMD under 100 microns) are still produced. Under some conditions droplet size must be increased to minimize drift.

When using oil-based carriers, several precautions must be noted:

- ! If the system was calibrated using water, recalibration with the oil mixture must be done because the different viscosity of the oil will change both the flow rate and the droplet size.

- ! Since oil and water do not mix, the spray system must be thoroughly dry or flushed with diesel fluid or equivalent before changing from water to oil carriers.
- ! When changing from oil to water, the system should be cleaned with water and strong detergent.

- ! Use water-based pesticides under low temperature, high humidity and low altitude conditions.

Spray Adjuvants

Spray adjuvants are added to mixes to alter their physical characteristics. Spreaders are surface active agents that reduce surface tension, causing them to spread more easily after impinging on the target area. However, reducing surface tension will also reduce droplet size during application, so they must be used with caution in conditions conducive to drift. Thickeners are water-soluble polymers that thicken water-based sprays and reduce the tendency of the mix to break up into very small droplets. They can be very helpful in lowering drift hazard by reducing the number of fines produced.

It is important to note that increasing the wind shear forces (either by increasing airspeed or by orienting the nozzle into the airstream) significantly reduces the positive benefits of thickeners for limiting the production of fines.

Nozzle Placement on the Boom

Droplets released into the airflow over the top and trailing edge of a wing may break up in the turbulence, decreasing average droplet size. Mounting nozzles below the turbulence reduces this effect significantly.

Drift Management

Finding the Balance

New research in particle behaviour, equipment design, spray efficacy and deposition analysis has given us a much better understanding of what happens to droplets once they leave the nozzle. With this information, there is a growing awareness and commitment throughout the industry to seek new ways to make aerial applications safer and more effective.

A primary focus of this ongoing research is finding new and better ways to limit hazards posed by drift. Significant advances have been made in reducing the drift hazard posed by small droplets. These involve new nozzle design, less volatile formulations and drift retardant additives, and a growing body of knowledge of the causes of, and ways to prevent drift. However, current technology has not yet found a dispersal system that will accommodate all application needs without producing a significant number of fine droplets.

We must also remember that small droplets are often most economical and effective in controlling a variety of pests, given the proper dispersal conditions. Finding the optimum balance between efficacy and drift control is becoming the central issue in the aerial application industry.

Ensure that all responsible personnel are aware of "go – no go" criteria and can readily communicate to others when conditions are not appropriate for an application.

Swath Displacement versus Drift

It is important to differentiate between swath displacement and drift.

Swath displacement refers to the movement of spray droplets by wind for relatively short distances from beneath the aircraft's flight path. It is generally desirable, since it tends to blend the spray pattern from multiple passes to give a more uniform coverage. Also swath displacement can be used to improve canopy penetration and impingement of droplets on foliage.

Drift refers to the small droplets or fines contained in all sprays that move out of the effective swath and target area.

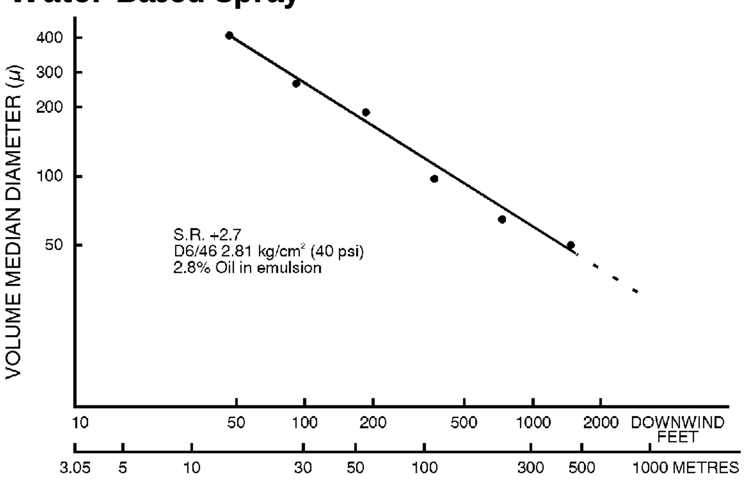
This is an important distinction for the applicator, since factors such as wind speed and direction may have minor effects upon swath characteristics and displacement, but major effects upon increasing the drift hazard.

Drift Losses

Pesticides that do not land in the target area can present serious problems to humans, animals, neighbouring crops and other sensitive areas. As well, drift lowers the effectiveness of spraying operations by reducing the amount of pesticide that actually controls the target pest.

Figure 39 shows the downwind recovery from a water-based spray initially at 450 microns VMD. The problem of drift posed by the smaller droplets is immediately evident.

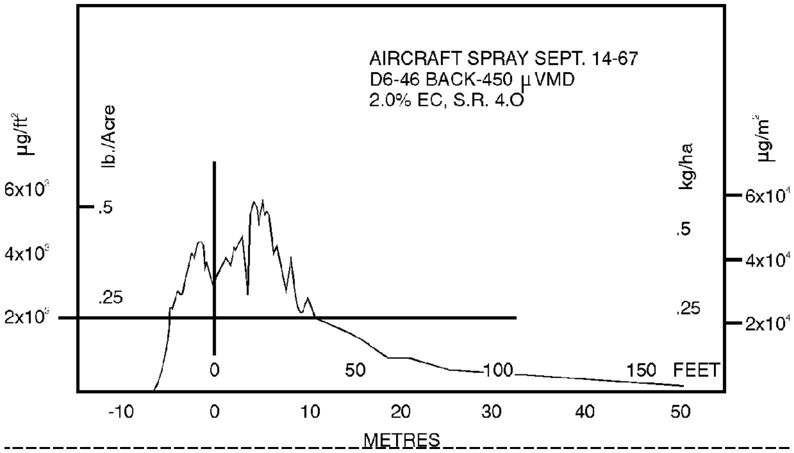
Figure 39. Downwind Dropsize Recovery from Water-Based Spray



Downwind drop-size recovery from field data taken with a water-base spray, initially at 450 μm VMD.

Even more useful is the data shown in Figure 40, illustrating the recovery rate from several passes during a field test.

Figure 40. Downwind Recovery from Multiple Passes



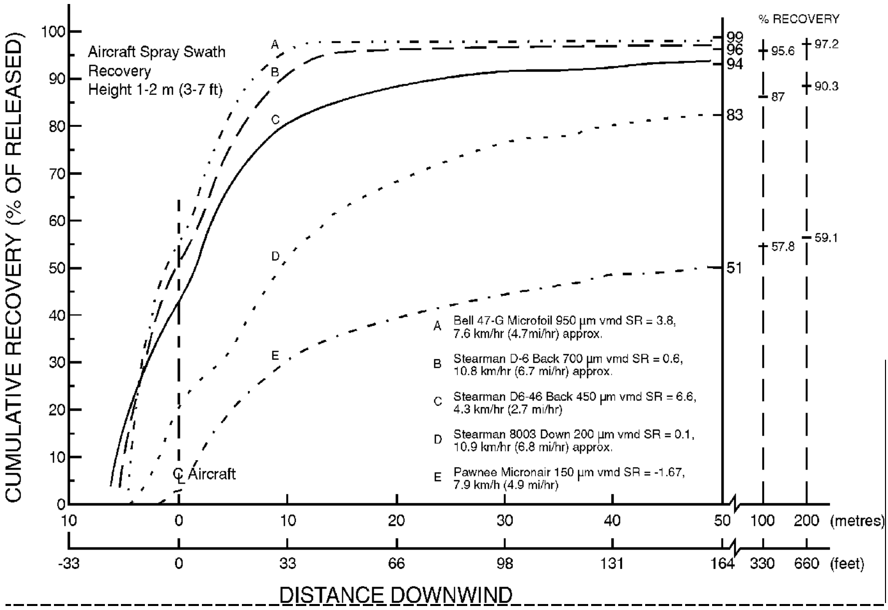
Less than 65% of the pesticide was recovered within the 15 m swath width. The additional material recovered rises slowly as the distance from the centreline increases as shown by the following table:

Distance from Centreline	Total Recovery (%)
15 m	65
25 m	70
50 m	78
200 m	82
400 m	84

The significant point is that almost 16% of the dispersed material goes beyond 400 metres of the swath centreline. This could result in a drift problem in an adjacent area. As well, the spray had an initial VMD of 450 microns, which would classify it as a coarse spray. For fine or medium sprays, the amount of drift would obviously be higher.

Figure 41 shows a comparison of the recovery rates for a variety of dispersal systems. In all cases there is a significant percentage of material that travels well beyond the effective swath width. However, the much lower drift potential of coarser sprays is also quite evident. This highlights the need for effective control of smaller droplets, specifically those below 100 microns in diameter.

Figure 41. Recovery Rates for Various Dispersal Systems



Causes of Drift

Droplet size is the single most important factor that influences drift.

Pesticide drift to non-target areas is usually the result of poor planning on the part of the applicator. As well as being inefficient, there is the potential hazard of damage to susceptible crops, animals or humans.

The primary causes of pesticide drift are:

- the release of smaller than intended droplets
- atmospheric conditions conducive to drift (i.e. high winds, high temperatures, inversions, low relative humidity, etc.)
- the lofting of droplets by wingtip or rotortip vortices
- boom length
- aircraft height.

Atmospheric Conditions

General Considerations

A high awareness of current and forecast weather conditions will permit safe and effective aerial application. The times should cover both that during application, and any time period following applications recommended by the pesticide manufacturer during which specific conditions must be met.

Specifically, the pilot should be aware of :

- ! cloud type, base, height and amount;
- ! temperature and relative humidty;
- ! wind speed and direction, gusts and squalls, storm and thunderstorm warnings;
- ! low-level turbulence (wind shear);
- ! thermals;
- ! inversions;
- ! frontal movements that would affect application or the effectiveness of the chemical after application, particularly the possibility of precipitation; and
- ! times of sunrise, sunset (these should be used in conjunction with local weather to determine the times when sufficient light exists to commence or continue operations).

Temperature and Relative Humidity

Always apply pesticides within the recommended temperature and relative humidities given on the label. High temperatures and low relative humidities increase evaporation from water-based droplets and thereby decrease droplet size. This means that, even if the optimum size were released, evaporation could reduce the droplet size sufficiently to create a drift hazard. In general, extra caution should be taken when applying water-based pesticides above 25 degrees C. or below relative humidities of 50 %. The amount of moisture on leaves due to precipitation or dew and the rate of drying may also be a consideration. *Continually monitor temperature and relative humidity during the application period and be prepared to discontinue operations when adverse conditions develop.*

Wind

Depending on the velocity, wind can enhance the effectiveness of an application or be a major source of problems. Low wind velocity can help distribute the pesticide evenly and impinge product on vegetation. However, spray drift is generally proportional to wind velocity: the higher the wind speed, the greater the drift. Normally, wind speed increases with altitude, a factor that must be taken into account when evaluating whether or not the wind speed exceeds that at which applications should be made. A velocity of 15 kph on the ground may mean a wind speed of 25 kph, or more, at 30 metres.

The type of surface will affect the difference in wind velocity between the surface of the ground or the plant canopy and that above it. In general, the rougher and less uniform the surface, the greater the difference in wind velocity. Thus, one could expect a greater difference in wind velocity between a forest canopy and a few meters above than for the same distance above a field of wheat.

Flying height should be reduced as wind speed increases to help minimize drift. In light wind conditions, application may be as high as 5 metres wheel height to aid in spray distribution. As wind speed increases, wheel height should be reduced to around 2 metres or less to help reduce the drift of small droplets.

An important point of flight safety must be raised here. Flying along with the wheels in the crop foliage, or flying just barely above, not only causes distortions in the overall spray pattern, but can be very dangerous. The pilot must concentrate much harder to ensure terrain clearance, with the result that other obstacles such as wires may be missed, and an accident may result. If you have to fly that low, you are flying in wind conditions that are outside acceptable limits.

Aerial applications should not be done in no-wind conditions. Here, drift may actually be increased because sufficient turbulence is not present to carry small droplets to the ground. Instead, they will be carried aloft by convective currents.

As well, no-wind conditions pose hazards to the applicator, because the aircraft will fly through pesticide from previous passes, which has not yet settled or been displaced downward. As pesticide collects on the windshield, visibility is greatly reduced, particularly in up-sun situations. Possible contamination to the pilot is also a concern.

Maximum allowable windspeed will vary with the type of pesticide being used, the height of dispersal, the size of area being treated, the proximity to sensitive areas, the VMD of the spray, etc.

Wind direction is another important consideration, particularly in light of the long distances downwind that small droplets may drift. Whenever sensitive bordering areas are encountered, treatment should be left until the wind is coming from the direction of that area.

Thermals

High temperatures on the ground can cause thermals that carry spray droplets upward and could prevent the spray from reaching the ground in the intended area.

Low-level Wind Shear

Under normal atmospheric conditions, surface friction retards the speed of the low level winds. Winds increase with altitude, with no sudden changes in speed or direction. However, low level inversions, which usually occur in the evening, separate the low level winds from the effects of surface friction by a thin layer of cool, dense air. This means that pilots may encounter sudden changes in wind speed at an altitude of only a few metres. These sudden changes may cause serious control problems. Particularly hazardous situations occur when the pilot of a heavily loaded aircraft encounters a sudden increase in tailwind on climb-out or pull-up at the end of a run.

Low-level wind shears should be suspected whenever an inversion is present. Observing the tops of trees for movement, launching a balloon or a test flight with a lightly loaded aircraft will confirm the presence of a low-level wind shear. If a low-level wind shear is present, takeoffs should be made in the direction of the shear (i.e., so the aircraft climbs into an increasing headwind). On pull-ups going downwind and where the aircraft will be climbing into an increasing tailwind due to the shear, the pilot should plan to pull-up early, leaving a large margin of safety so that aircraft control and obstacle clearance is assured.

Inversions

Air temperature normally decreases with altitude. This is called a normal lapse condition. It means that a “parcel” of air displaced upward will continue to rise since it is moving into a region of cooler, denser air. Under some conditions, a thin layer of cool air may form above the ground under a warmer layer. This is called a temperature inversion. In inversion conditions an air “parcel” displaced upward will not continue to rise because it is denser than the air into which it is moving. By the same token, air displaced downward will be unable to penetrate the denser inversion layer. The height to which this inversion extends and the reasons for it will vary.

It is critical that applicators be able to determine when a temperature inversion exists because spraying under those conditions can result in severe drift problems.

The most common cause of temperature inversions is rapid radiation of heat from the ground to the air in the early morning or late afternoon or evening hours when the sun is low and there is little or no wind. Low-lying fog patches, smoke plumes or dust, which rise, abruptly cool off and hang a few metres above the ground are often associated with inversion conditions.

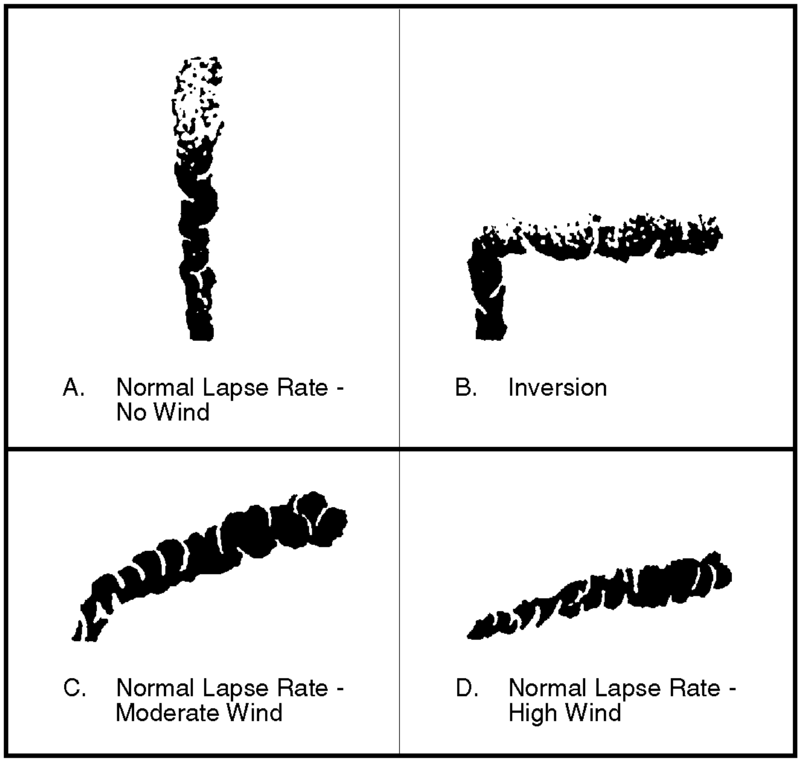
The drift problem arises when the cool layer is sufficiently dense that a spray cloud generated above will not penetrate it. The droplets may then flow along contours far away from the target crop and settle out where they could present a serious hazard.

Inversions may also be caused by factors such as the flow of cooler air down a slope or by inflow of cool air close to the ground from a large body of water. Always be aware of this phenomenon when spraying near a lake or river.

The most practical way to determine if an inversion exists is to observe a smoke plume that originates at or close to ground level. Plumes that originate from tall smokestacks or chimneys are not good indicators as they may be above the inversion level.

Figure 42 shows examples of the appearance of a smoke plume under different conditions of atmospheric stability.

Figure 42. Smoke Plumes vs Atmospheric Stability



Spraying should be avoided in A, a normal lapse rate with no wind, and in B, a temperature inversion. (Unless the height of the inversion is above the spraying height of the aircraft). In Figure 42A, all the convective currents are upward, which will carry droplets aloft. In Figure 42B, there are no convective currents so the spray stays in a layer close to (but not contacting) the ground.

Figure 42C shows the appearance of a smoke plume under ideal atmospheric conditions: the plume rises and is dispersed by a light to moderate wind. Figure 42D shows a plume affected by strong wind conditions.

An OAT (Outside Air Temperature) gauge on spray aircraft permits early identification or confirmation of an inversion when temperature on the ground can be compared with that at application height. Temporarily discontinue the application until atmospheric conditions are appropriate.

Review Questions - Spray Characteristics

1. All atomizers produce a range of droplet sizes; the spray can be characterized by the volume median diameter, which is the droplet size that divides the spray volume into two equal volumes.

   True False

2. Droplets of 100 microns or less are generally considered prone to drift.

   True False

3. Droplet size will influence the coverage, the degree of sedimentation, and the impact of air movement and ultimately spray efficacy.

   True False

4. Too large a droplet size can result in overdosing some areas within a spray area.

   True False

5. Droplet sizes decrease as the speed of rotation decreases in a rotary atomizer.

   True False

6. Angling hydraulic nozzles directly into the wind may cause pesticide build up and flow problems.

   True False

7. With electrically driven atomizers droplet size is independent of airspeed.

   True False

8. Reducing airspeed reduces the size of droplets produced by a hydraulic nozzle.

   True False

9. Increasing the pressure to increase the flow rate may be less appropriate than increasing the number of nozzles.

   True False

10. Relative humidity and temperature will not impact on droplet integrity of oil-based pesticides applied undiluted.

True False

11. If an oil-based formula is used in an aircraft calibrated with water, the flow rate must be verified.

True False

12. Droplet size can be reduced with the use of thickening agents.

True False

13. The boom pressure will influence the amount of material dispersed with hydraulic and rotary nozzles.

True False

14. Swath displacement because of wind generally is desirable during a spray application.

True False

15. Factors that increase drift generally have a major impact on swath displacement.

True False

16. The amount of product that could be lost to drift when the VMD is 450 microns is minimal and the drift droplets are generally too small to be of concern.

True False

17. Droplet size is the major contributor to drift problems and consequently, relatively large droplets should be used with herbicides.

True False

18. Proper maintenance, pressure, nozzle selection and orientation can eliminate drift problems.

True False

19. Although calibration is appropriate under no-wind conditions, actual application is not.

True False

20. Inversions are caused by thermals pushing the air mass down to the ground, which can reduce drift.

    True False

21. Define the best meteorological conditions for spraying.

22. What is the single most important factor affecting the swath and the effectiveness of a liquid application?

Section 4 — Calibration

Goals of this Section

When you have completed this section, you should be able to:

‘ describe calibration methods for liquid dispersal systems and solid dispersal systems

‘ calculate pesticide load requirements, including:
- total spray volume
- number of loads required
- total amount of pesticide required
- pesticide amount per load

Introduction

Precise adjustment of the amount of material dispersed by the aircraft in a unit of time is an essential prerequisite to application of the proper amount of pesticide to the target area. The dispersal of liquid and solid materials differs considerably due to the different handling equipment and flow characteristics.

Application rate is the amount of material applied per unit area (litres/hectare, kilograms/hectare). It is dependent upon:

! flow rate
! swath width
! aircraft speed

Flow rate is the volume of liquid dispersed per unit time (litres or gallons per minute) or the weight of solid dispersed per unit time (kg/min).

Unless the actual flow rate of a system is known, it is impossible to apply correct application rates. This could result in under-dosage of the pesticide with little or no control, or over-dosage that is illegal, wasteful and could cause unwanted damage. Therefore, it is important to know the actual flow rate of a system to adjust the system to apply the correct rate of product or pesticide mixture.

Consider the consequences of lack of or inaccurate calibration:

! inadequate coverage in target area
! inadequate dosage applied, resulting in poor target pest control
! violation of label and severe penalties, which may be incurred by illegal over-dosing

- high cost of using too much pesticide
- injury to persons, wildlife, crops and other non-targets.

Calibration Procedures for Liquid Dispersal Systems

In practice, errors in pressure gauges and variations in equipment will mean that actual flow rates will differ from those given in manufacturers' tables. Flow rate calibration is required to determine equipment control settings (e.g., boom pressure, gate setting) that will give the required flow rates for a specific application rate. With flow monitors, the process involves calibration of the system to accurately calibrate the flow monitor so it may serve as an accurate tool for the pilot.

Flow rate verification should be performed:

- when equipment is new
- at the beginning of each season
- when changing dispersal materials or rates
- when significant discrepancies arise between the actual size of the area treated per load versus that calculated.

Once the pilot has verified the flow rate, the following calculations can be made:

- the total amount of spray mix required for a treatment
- the number of loads required to complete a job
- the amount of pesticide product to add to a spray tank.

Before arrival on-site for flow rate calibration, the aircraft must be properly equipped with a dispersal system that will provide the required droplet size, swath distribution pattern and the desired output.

Ideally, the calibration test should be done on-site, immediately preceding actual dispersal operations to eliminate errors resulting from worn or different equipment.

If the calibration procedure cannot be done with the carrier that will actually be used during application, the viscosity of the test fluid (usually water) compared with the actual carrier must be taken into account. For example, highly viscous formulations will have slower flow rates than water, requiring follow-up verifications of flow rate during actual runs.

Aircraft, especially helicopters with hydraulically or electrically driven pumps, can be calibrated on the ground. Fan-driven pumps can be calibrated on the ground if the aircraft propeller can generate sufficient airflow past the fan blades to obtain the needed boom pressure. Otherwise, a test flight is required to confirm ground calibrations.

Flow Rate and Output Formulae

Use the following formulae to determine the required flow rate and compare with the actual flow rate determined during flow rate verifications:

$$\text{Required Flow Rate (L/min)} = \frac{\text{Application Rate (L/ha)} \times \text{Swath Width(m)} \times \text{Airspeed (kph)}}{600}$$

$$\text{Required Flow Rate (gal/min)} = \frac{\text{Application Rate (gal/ac)} \times \text{Swath Width (ft)} \times \text{Airspeed (mph)}}{495}$$

$$\text{On-site Verification of Actual Flow Rate} = \frac{\text{Volume Sprayed}}{\text{Spray Time}}$$

Note that the required flow rate will have to be converted to American gallons/acre if the nozzle flow rates are given in these units.

System Priming

Before determining actual flow rates, the system must first be primed. Add a load of carrier (water or diluent) or product sufficient to cover the pump intake and completely fill the entire system plumbing (50–100 L). Evacuate air from the boom ends by opening the end caps slightly or installing valves in the boom tips. Spray until the pressure begins to drop, then close the spray valve. The spray system is now primed.

Flow Rate Verification Methods

As an example, an aircraft with 24 nozzles flying at 145 kph is to be used for an application rate of 28 litres/hectare. The boom pressure can vary from 138 to 276 kPa, and the swath width has been found to be 14 metres.

Do not rely on the aircraft hopper markings for calibration because the residual volume (the volume left in the hopper that cannot be sprayed out) is included.

From manufacturers' tables, it is known that 24 nozzles with D7 orifices and #46 cores will deliver 27 litres/hectare at 138 kPa. At 207 kPa, output will be 34 litres/hectare. Extrapolating, the predicted boom pressure will be 152 kPa for an output of 28 litres/hectare.

You can now proceed with flow rate calibration using one of the following four methods:

Flowmeter Method: Calibration using a flowmeter is the safest, most efficient and most accurate method. The recommended way to do this is to turn off the flow at all atomizers/nozzles and attach a hose to the aircraft boom outlet that leads to a second, standardized (previously calibrated) flowmeter and then back into the aircraft tank. A quantity of product is then loaded into the tank, the pilot runs the aircraft, activates the spray system, and establishes the required flow rate. Finally the aircraft flow rate is compared with the flow rate of the standard flowmeter, and adjustments are made as necessary.

In the event that a standardized flowmeter is unavailable, an alternative method is to spray out a known volume of product, then the actual volume sprayed is compared with the volume indicated on the flowmeter. The percentage difference is then applied to change the flow monitor reference number. The procedure is continued until indicated and actual volumes are the same. Manufacturers' guides provide specific calibration procedures for the various flow monitors now available.

Fixed Timing Method: A sufficient amount is loaded so that spraying can be continued for a pre-arranged time without depleting the system. After spraying, the actual volume sprayed will be the amount required to load to the initial level.

In practice, spray times are one minute for heavy application rates, and two minutes for light rates.

Actual and required flow rates are calculated. The differences between the two will determine the change in boom pressure or flowmeter number to produce the required flow rates.

Continuing the example:

$$\text{Required Flow Rate} = \frac{28 \times 14 \times 145}{600} = 95 \text{ litres/min}$$

On the test flight, with an initial load of 492 litres, it was found that, at 152 kPa after one minute of spraying, 405 litres remain in the hopper, i.e., 87 litres were dispersed. Thus, a small increase in boom pressure should result in the required flow rate.

Open Timing Method: A measured amount is loaded and sprayed until the pressure begins to fall. The spray valve is then closed. The actual amount sprayed will be the amount added initially to the system.

Time is measured between booms on and booms off for calculating actual flow rate. System adjustments are then made so that actual flow rates equal required. This method will not usually give as accurate a flow rate as the fixed timing method.

Using the example, 95 litres were added to the hopper after priming. At a pressure of 152 kPa, it took 65 seconds to completely dispense the load, giving an actual flow rate of 87 litres/min. A slight increase in boom pressure will bring the flow rate up to the required flow rate of 95 litres/min.

Known Distance Method: Volume to be sprayed over a known distance is calculated as follows:

$$\text{Volume (gal)} = \frac{\text{Swath Width (ft)} \times \text{Swath Length (miles)} \times \text{Application Rate (gal/ac)}}{8.25}$$

$$\text{Volume (L)} = \frac{\text{Swath Width (m)} \times \text{Swath Length (km)} \times \text{Application Rate (L/ha)}}{10}$$

This is compared with the actual measured volume from a flight test over that distance, and system adjustments are made accordingly. This method is common in agricultural operations, with distances varying from 1 kilometre for high volume work to 2 kilometres for low-volume work.

For example, with a field length of 1.6 kilometres:

$$\text{Volume} = \frac{14 \text{ m} \times 1.6 \text{ km} \times 28 \text{ L/ha} = 63 \text{ litres}}{10}$$

Thus, the hopper should decrease by 63 litres after each pass at the correct application rate. On the test flight at 152 kPa with an initial load of 492 litres sprayed over one kilometre, 435 litres remained in the hopper, i.e., 57 litres had been sprayed. Again, increasing the pressure slightly will bring the flow rate up to that required.

Calibration Tips

! Monitor operational application and flow rates continually after initial calibration, since conditions may vary.

! Keep records of all load parameters (boom pressure, gate settings, etc.). These will allow easier re-calibration in the future.

! Verify the accuracy of spray tank/hopper level markings by comparing them to loads of known size.

! For liquid calibrations, the deviation between calculated and actual flow rates should be within 5 %. If actual rates are too high, check for:
- system leaks
- pressure gauge error
- excessive nozzle wear.

! The deviation between actual flow rate and the manufacturer's specified flow rate for the individual nozzles should not exceed 15 %. If so, replace worn nozzles.

- If actual flow rates are too low, check for:
  - a viscosity higher than water
  - any blockages in the system
  - incorrect pressure gauge reading
  - insufficient number of atomizers.

- Keep in mind that flow rate varies as the square root of the pressure. For example, considering 138, 172 and 207 kPa, their respective square roots are 11.7, 13.1 and 14.4. If the flow rate at 138 kPa was 95 litres/min, flow rates at 172 and 207 kPa would be calculated as follows:

  $$\text{Flow Rate (i.e. at 207 kPa)} = \frac{95\ \text{L/min} \times 14.4}{11.7} = 117\ \text{L/min}$$

Calculating Pesticide Requirements

- Determine application rate and volume to be used.

- Calculate total volume of spray mix required:

  Total Volume = Area × Required Application Volume

- Using a load size suitable for the type of aircraft, calculate the total number of loads required:

  $$\text{Number of Loads Required} = \frac{\text{Total Volume}}{\text{Load Size}}$$

  Try to keep this figure a whole number (i.e., if the initial calculation requires 9.3 loads, divide the project into 10 standard loads of a slightly smaller size; or 8 full loads and 2 small loads for trimming).

- Calculate the amount of pesticide required for the total area, using the manufacturer's recommendations:

  Amount of Pesticide = Total Area × Pesticide Rate

  Note: Pesticide Rate is defined as the amount of pesticide product to be applied per unit area according to label instructions.

- Calculate the amount of pesticide/load:

  $$\text{Pesticide Amount/Load} = \frac{\text{Total Pesticide Amount}}{\text{Number of Loads}}$$

Sample Calculations

Definitions:

Application Rate:	specified rate or dosage of pesticide to be applied for control purposes, usually expressed in weight (grams, g) of active ingredient per hectare (g/ha), or litres of product per hectare (L/ha).
Application Volume:	the total volume of pesticide and carrier specified or required to deliver the prescribed application rate, expressed in litres per hectare (L/ha).
Swath width:	the width, usually expressed in metres, that receives an application of pesticide from one sprayer pass.
Track spacing:	the distance between flight lines on a spray block. It is determined by averaging several measures of effective swaths for a particular aircraft/spray gear combination.
Flow Rate:	the amount of pesticide and carrier that is flowing from the spray system in a measure of time, usually expressed in litres per minute (L/min).
a.i.	active ingredient

1. How many litres of a herbicide are needed to treat 30 hectares if the application rate is to be 5 litres of product per hectare?

   5 L/ha × 30 ha = 150 L

2. You are to spray a block that is 72 ha in total. Within the block there is a ‘no spray’ zone 250 × 320 m. You will be using a herbicide at an application rate of 6 L/ha in an application volume of 35 L/ha.

   a) How many litres of product are needed for the project?

      no spray area = 250 × 320 = 80,000 m^2 = 8 ha

      actual spray area = 72 ha ! 8 ha = 64 ha

      6 L/ha × 64 ha = 384 L product

   b) How many litres of water will be needed for the project:

      35 L/ha app. vol ! 6 L/ha pesticide = 29 L water/ha

      29 L × 64 = 1856 L

c) If the aircraft hopper has the capacity to hold 700 L, how many loads will be needed to complete the project?

35 L/ha app. Vol × 64 ha = 2240 L/ha total spray

2240 L/700 = 3.2 loads

3. If your spraycraft's operational speed is 185 kph and it sprays a swath of 23 m, how much area does it spray per minute?

185 kph = 3.083 km/min = 3083 m/min

3083 m/min × 23 m = 70,909 m^2 /min = 7.09 ha/min

b) How much would it spray in an hour?

60 × 7.09 = 425.4 ha

c) How long would it take to spray a hectare of land?

7.09 ha per 60 sec = 60 sec/7.09 = 8.46 sec/ha

4. If your spraycraft sprays 5.5 ha/min and your desired application volume is 30 L/ha, what would your desired flow rate (L/min) be?

5.5 ha/min × 30 L/ha = 165 L/min

b) Your spraycraft has 40 nozzles. What is your desired flow rate per nozzle (L/min/nozzle)?

165 L/min/40 = 4.13 L/min/nozzle

5. Use the following information to calculate:

a. total flow rate (litres/minute)
b. flow rate/nozzle (litres/minute/nozzle)

Information required:

Aircraft: Ag Truck	Number of Nozzles: 38
Track spacing: 23 m	Application Volume: 33 L/ha
Flying speed: 110 mph	

110 mph = 177 kph = 2.95 km/min = 2950 m/min

2950 × 23 = 67,850 m^2/min = 6.785 ha/min

a. 33 L/ha × 6.785 ha/min = 223.91 L/min
b. 223.91/38 = 5.89 L/min/nozzle

6. Use the following information to calculate:

   a. total flow rate (litres/minute)
   b. flow rate/nozzle (litres/minute/nozzle)

   Information required:

   Aircraft: Pawnee — Number of Nozzles: 40
   Track Spacing: 23 m — Application Volume: 33 L/ha
   Flying speed: 175 kph

   175 kph = 2.917 km/min = 2917 m/min

   2917 × 23 = 67,091 m^2/min = 6.7091 ha/min

   a. 33 L/ha × 6.7091 ha/min = 221.4 L/min
   b. 221.4/40 = 5.54 L/min/nozzle

Calibration Procedures For Solid Dispersal Systems

Unlike liquid dispersal systems, spreaders do not come with published flow rates. These must be established through trial and error. The problems in the initial calibration of solid dispersal systems include:

- the swath width is not known
- flow rates cannot be calculated until the swath width is known
- until the flow rates are established, the swath width for that flow rate cannot be determined.

With liquid dispersal systems, calibration can be done with water, with the pressure changed to account for the differences in viscosity between water and the actual mix. With solid dispersals, the use of any inert substance would have little value, as the size and density of the material would have to be nearly identical to the actual application material to be of any use. Thus, the actual material must be used for calibration unless the manufacturer can supply blanks (the granular material without the active ingredient).

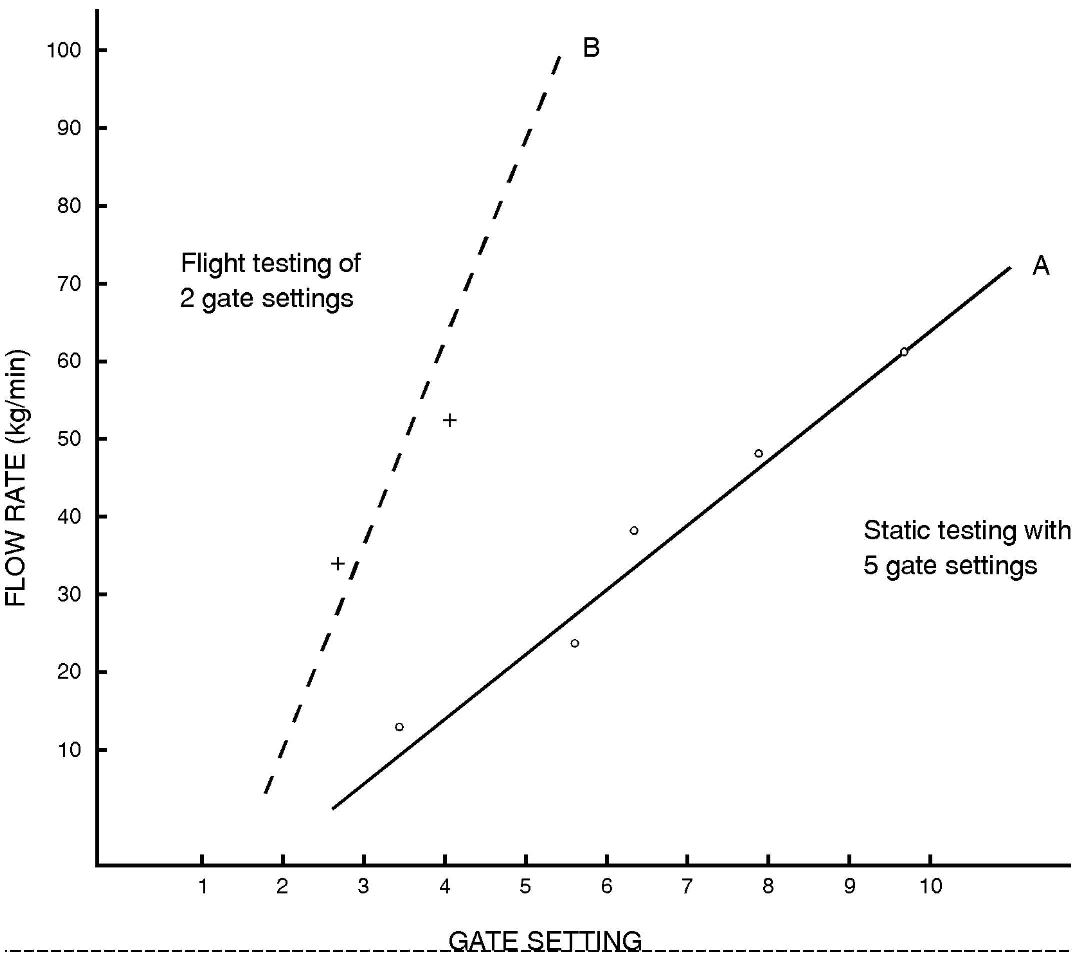
You can use the following method for calibration of solid dispersal systems :

Step 1 - Approximation of gate setting versus flow rate.

- Set up the hopper gate without the spreader attached.
- With the hopper at least half full and the aircraft tail raised to the flying position, open the gate for a timed interval, catching the material in a large pan and weighing the output.
- Repeat this for a series of different gate openings and plot the results on a graph of flow rate versus gate setting.
- From this graph, you can establish a rough approximation of gate setting for a given flow rate.

Line A in Figure 43 shows the results of tests using a granular blank timed over one-minute intervals for various gate settings.

Figure 43. Graph of Granular Flow Rate vs. Gate Setting



Step 2 - Approximation of required flow rate.

The relationship between flow rate (kg/min), application rate (kg/ha), swath width (m) and groundspeed (kph) is given by the formula:

$$\text{Flow Rate} = \frac{\text{Application Rate} \times \text{Swath Width} \times \text{Groundspeed}}{600}$$

Since the application rate and groundspeed are known, a flow rate can be estimated by assuming a swath width. A good place to start is the aircraft wingspan. The actual swath width will be established during a test flight.

As an example, the label rate for a granular pesticide is 8 kg/ha. Given a groundspeed of 185 kph, and assuming a swath width of one wingspan of 14 metres, the required flow rate would be:

$$\text{Flow Rate} = \frac{8 \times 14 \times 185}{600} = 34.5 \text{ kg/min}$$

Step 3 - Flight Testing

- Using the gate setting corresponding to this flow rate, load a measured weight of material into the hopper. Carry out a short timed flight test (one minute is adequate) dispersing the material over the area to be treated. Centre the flight line perpendicular to a bare strip of ground approximately one metre wide.

- Weigh the material remaining in the hopper, after landing. In practice, flow rates encountered in flight may vary greatly from the static flow rate. Thus, the original flow rate graph established during ground tests must be corrected to reflect these differences.

- Because granular flow is usually directly related to gate opening size, a new reference line can be easily drawn. For example, if the flight test showed a flow rate twice that of ground testing for two gate settings, extend a line through these new points to construct the new graph (line B, Figure 43).

- Ground personnel can count the granules per unit area (i.e., granules/m^2) found on the bare strip, and plot them on a graph of swath width versus density. The point at which the density is half that across the centre of the swath will be the effective swath width. Using the new graph and measured swath width, carry out the flight test procedure again. This may require several tests before an accurate determination of swath width and flow rates are established.

- The above procedure is appropriate for a gravity flow system. However, some solid dispersal systems, for example the Simplex System, involves a rotating drum, which turns to carry material from the hopper and through the system. With this type of system, you need to determine the output in kilograms per the number of revolutions that typically occur within a minute during an application flight. As with the previous procedure, this should be repeated for a series of gate openings, and plot the results.

! The applicator should be aware that the spreader attachment will have a series of baffles to distribute the granules relatively evenly across the swath. Depending on the granule mesh size of the product bridging may occur at the lower rates resulting in disruption of the rate and poor distribution of the product, on the ground.

Review Questions - Calibration

1. Calibration of flow rate is essential for a safe and effective application.

   True False

2. Flow rate is the volume dispersed over a given area.

   True False

3. Before calibration, the aircraft should be equipped with the dispersal system for which the swath characteristics and output have been determined.

   True False

4. When priming the system for calibrating liquids, load enough liquid to fill the entire system plumbing, then begin to spray until you think the liquid is throughout the system. If the pressure drops, prime has been lost and the system will have to be loaded again.

   True False

5. Flow rate can be adjusted by changing pressure or the number of nozzles.

   True False

6. Flow rates are calibrated, not flow monitors.

   True False

7. For the initial calibration of granular flow rates, it is acceptable to assume that the swath width is the same as the aircraft wing span until the swath width can be verified during a test flight.

   True False

8. For operational situations, the deviation between calculated and actual flow rates for liquid systems should be within 5%.

   True False

9. If the actual flow rates are less than those when the craft was calibrated with water, the pesticide may have a lower viscosity than water.

   True False

10. Flow rate varies inversely with pressure.

True False

11. You are to spray a block that is 84 ha in total. The block contains a “no spray” zone of 220 × 200 m. You will be using a herbicide at an application rate of 7 L/ha in an application volume of 36 L/ha.

(a) How many litres of product are needed for the project?
(b) How many litres of water will be needed for the project?

CHAPTER 8 - EMERGENCY RESPONSE

Goals of this Chapter

When you have completed this chapter you should be able to:

‘ describe approaches to reduce the potential for accidents

‘ describe procedures required in various in-air emergency situations, as well as emergencies on the ground.

Introduction

Safety must be the number one priority. If you come across something that is unsafe, stop what you are doing and remedy the situation before a minor incident becomes a catastrophic event. Acts of carelessness or neglect may result in serious injury or death to pilots, mixers and loaders, flaggers or others involved in the operation as well as to bystanders.

While not all circumstances leading to accidents can be predicted, detailed planning for emergency response procedures will provide a solid foundation for effectively handling any mishap. In addition, such planning can lead to a better understanding of the roles each crew member must play in the team effort needed to control an emergency situation.

Emergency Planning

The following approach will help you develop sound emergency response procedures:

- List all of the basic types of accidents/incidents that are likely to happen in the operation.
- Develop plans and procedures for limiting the potential harm and controlling the damage from accidents.
- Assign crew responsibilities for each of the roles necessary to implement the plan, so that they can properly carry out their duties.
- Ensure all crew members know the phone numbers of the nearest medical facilities and poison control centre.
- Whenever possible, have all crew members take a certified first aid course such as St. John’s Ambulance. They should also be well briefed on the symptoms of chemical poisoning pertinent to the job.

- Notify the local hospital or medical centre of the pesticides being used to ensure that antidotes are in stock in case of accidental poisoning of staff.

- Decide upon a visual signal system, particularly a mandatory “Cease Operation” signal. Smoke bombs, vehicles, lights or flags can be used as signals.

An engine or system malfunction is difficult even under ordinary circumstances. Since most aerial application is done under 30 metres, the need for correct emergency response is especially evident. Correct response procedures are possible only if well planned ahead of time, and practised until they become instinctive.

Preventative Measures

The two main sources of accidents are collision with obstructions and inadvertent stalls. Adequate training and a “defensive flying” approach will reduce the possibility of a major or minor mishap.

Since engines will be working at high power levels for extended periods of time, a thorough preventative maintenance program is essential. You must adhere strictly to periodic check and inspection schedules. As well, the morning pre-flight inspection of the aircraft and systems must be detailed and complete.

As you gain experience with a particular aircraft, there is a tendency to keep increasing load size. This trend must be approached with extreme caution. Aside from the time lost in trying to position a heavily loaded aircraft with minimal manoeuvrability, a heavyweight condition may make it impossible to avoid obstacles.

Training for aerial application procedures should cover early recognition of stall symptoms and instinctive stall recovery procedures, and flying well within capabilities of the aircraft and the pilot. Also, immediate and correct response to other in-flight emergencies especially at low altitudes should be handled instinctively. Pilots must know the contents of the aircraft manual thoroughly. The emergency procedures are particularly important.

Rapid loading turnarounds demand a “last chance” checklist to ensure that all critical items are checked before takeoff. The following check is suitable for most single-engine fixed-wing aircraft, and is to be used only if the pilot is simply re-loading and does not leave the aircraft. Should the pilot leave the aircraft for any reason, a complete pre-takeoff check (as outlined in the aircraft manual) must be completed.

H Harness and hatches - secure
T Throttle tension and trim
M Mixture - full rich
P Prop - full fine
F Fuel - sufficient, Flaps - as required
G Gauges
S Switches

This "last chance" check is also useful as an indication of fatigue. If the entire check or any item is omitted, this is an indication the pilot is losing concentration and should take a rest break.

The normal and emergency operating procedures section of the aircraft manual must be carefully studied. Any indication of abnormal engine performance must be carefully investigated immediately. It is often tempting to go ahead with "just one more load" rather than check out a problem immediately.

Emergency Situations

Jettisons

The emergency load jettison may be necessitated by engine problems or insufficient height to clear an obstacle. The dump feature of most aerial application aircraft provides for an immediate increase in climb performance, glide capability and manoeuvrability. As well, a lower weight means greatly reduced risk of damage during an emergency landing.

If safe flight becomes questionable or impossible and a solution is not immediate, the entire load should be jettisoned. Partial jettison may not decrease weight sufficiently to remedy the situation and may distract the pilot from other critical areas.

When using new aircraft or at the beginning of each spray season, it is good practice to completely jettison a full load of water at a safe altitude to become familiar with the aircraft response in such a situation. Most aircraft have a very pronounced pitch-up associated with an emergency jettison, which may make control difficult, if not anticipated.

Forced Landings

Any procedure will be ineffective unless practised regularly. Periodically simulating a forced landing ensures that the required responses will become instinctive. Keep in mind that engine-out glide capability may be considerably less with idle power setting used for practice.

When working a particular area, check roads, pastures, clearings, etc., to assess their suitability as emergency landing sites.

Observe the following precautions with a forced landing:

- jettison the load whenever possible
- land into the wind, three point attitude.

As a precautionary measure, the pilot should call into the base at predetermined intervals. If a call is missed, the aircraft will be assumed missing.

Heavyweight Landings

Deteriorating weather, winds above spray limits or equipment failure are some of the reasons why a pilot may be required to land with a full load. This can be done quite safely with allowances for increased final approach speeds and landing rollout. Consult the aircraft operating manual for specific details. Should there by any question as to safety, full or partial jettisoning of the load over a suitable area is in order.

For tailwheel aircraft, the approach should be for a wheel landing, as it is easy to misjudge stall point in a 3-point attitude. In a heavyweight condition, dropping even two feet in a full stall could impose severe structural loads.

Low Level Engine Failures

Complete engine failures are rare. Rather, progressive engine problems lead to more severe problems. However, if a total power failure should occur while working an area, it will be very difficult to do anything other than land straight ahead. Abrupt turns at low altitude in an emergency may cause a serious accident, whereas a controlled landing is most likely to result in little or no damage.

It is vital that partial/complete engine failure response procedures are thoroughly understood and practised regularly. At the low altitudes encountered in aerial application, emergency responses must be immediate and appropriate the first time.

The pilot with an emergency must notify members of the flight team or the base; the base can then prepare for an inbound disabled aircraft.

Wirestrikes

After striking a wire, the first action required is immediate application of full power, since there is the possibility that a considerable length of wire may be trailing behind the aircraft. All attempts should be made to keep the aircraft under full control, including full or partial jettisoning of the load.

If the aircraft can gain altitude, it should climb to a safe height to avoid the possibility of any trailing wires catching on other obstacles. A visual check of controls should be carried out, followed by cautious checking of flying characteristics as preparation for landing as soon as possible. If a length of wire is being trailed, the final approach must be planned to avoid any obstacles that might become snagged by the wire.

Aircraft Crashes

The safeguarding of life must be the sole focus of the response to an aircraft crash. Under no circumstances should anyone’s safety be jeopardized by attempts to save the aircraft.

Correct response to a crash often means the difference between minor injuries and loss of life. This includes:

- proper safety equipment in the aircraft, on the pilot and within quick access to ground crew members
- thorough training of all personnel in emergency response
- a detailed emergency response plan with specific crew responsibilities.

Pilot Procedures: If time permits, turn off the battery master and mags before leaving the aircraft.

- Do not attempt to extinguish a fire if it in any way jeopardizes your safety
- Wash off any personal contamination as soon as possible
- Even though you may not have any serious injuries, you should go to the nearest medical office as soon as possible for a complete examination.

Ground Crew Procedures: When an aircraft crashes, there is a natural tendency to rush into the scene with no plan of action. Follow the planned and practised emergency response procedures. The primary responsibility is to assist the pilot without jeopardizing personal safety. Go immediately to the crash site and take a fire extinguisher.

If the aircraft is not on fire:

- If the pilot is not seriously injured, help him/her exit the aircraft.
- If the pilot is seriously injured, DO NOT MOVE HIM/HER. Provide first aid until experienced medical help arrives. Moving a trauma victim improperly may seriously add to injuries already sustained.
- As soon as possible, get assistance. Call for the nearest ambulance or doctor, ensuring that you provide the exact location of the accident.
- Go with the ambulance to ensure medical personnel know which type of pesticide was being used.

If the aircraft is on fire:

- Use a fire extinguisher if available and the fire is not too dangerous.
- Avoid any exposure to smoke and flames. You will not be able to assist if you become incapacitated. Keep in mind information on the pesticide MSDS pertinent to fire.
- Try to get the pilot out and moved to a safe location.
- Check the pilot and wash off any chemical contamination as soon as possible.
- Seek the assistance, as soon as possible, of medical and/or fire fighting professionals.

Fire at the Base

- Review the pesticide material safety data sheet in advance to determine the hazards associated with pesticide fires.
- The person who discovers the fire is not to rush in and jeopardize his/her safety; suppress the fire only if you are sure you are able to do so safely.

- If you are unable to suppress the fire, notify the person in charge of the emergency situation.

- The ground crew should attempt to fight the fire only if they are sure it can be done with equipment on hand.

- If this is not possible, evacuate the area and call in fire fighting professionals.

- Call the provincial spills response centre (if there is one) to notify them of emergency.

Fuel and Pesticide Spills

- The person who discovers a spill must notify the crew supervisor or the individual responsible for handling such emergencies.

- The person in charge should begin with rescue or first aid; initiate containment; and proceed with clean up procedures. He/she will notify the appropriate government agencies.

Guidelines for Handling Spills

The following guidelines may be used for handling spills. **They are to be used to supplement information from the product label and other key agencies, not to replace it.**

- Remove all persons and animals from the spill area. Extreme caution should be exercised in entering a contaminated area. Adequate personal protective equipment should be worn.

- Apply general first aid; remove contaminated clothing and thoroughly wash affected skin area with soap and water.

- Isolate the area so that no unauthorized person, animal or vehicle is exposed or contaminated by moving through the spill, or is exposed to fumes from the pesticide. Establish a decontamination line around the perimeter such that anyone entering the area must wear adequate protective equipment; and persons and/or vehicles leaving the spill area can be decontaminated.

- Contain the pesticide to prevent further environmental contamination, in particular watercourses. If possible, stop containers from leaking. A barrier may be made of soil, or an absorbent material such as vermiculite or pet litter.

- Call the following organizations to obtain appropriate information on the clean up and decontamination of the spill area:

  - provincial spills response centre
  - local provincial pesticide authority
  - the distributor or registrant of the pesticide product.

- First aid information and advice from the local police, fire and/or works departments.

Review Questions – Emergency Response

1. It is imperative that all personnel on a spray operation be thoroughly briefed and tested concerning emergency response procedures.

   True False

2. Defensive flying can readily reduce the possibility of a mishap.

   True False

3. If the aircraft has been performing normally, a pre-takeoff check is necessary only for the first flight of the day.

   True False

4. A practice jettison of a load should be conducted at a low altitude under operational conditions to enable the pilot to become familiar with the aircraft response.

   True False

5. It is appropriate to jettison the load in a forced landing situation provided the pilot is not endangering the lives of bystanders.

   True False

6. With an aircraft crash, if the pilot appears unhurt, work to minimize further damage to the aircraft.

   True False

7. If the pilot is unconscious and the aircraft is not on fire and gasoline is not leaking turn off the battery master and mags and send someone for medical assistance.

   True False

8. If pesticide has contaminated the pilot as the result of a crash, the contamination should be washed away and even though serious injuries may not be apparent, the pilot should go to a medical facility as soon as possible with information on the pesticide.

   True False

9. If the aircraft is on fire use a fire extinguisher if the fire is not too dangerous and make every attempt to remove the pilot without becoming incapacitated yourself

   True False

10. To prevent damage to the environment from a spilled pesticide, wash the area with lots of water to dilute the pesticide.

   True False

ANSWERS TO REVIEW QUESTIONS

Chapter 1: Regulations

1. Yes, except for farmers who hold a flying farmer exemption.
2. CAR means Canadian Air Regulations. Aerial applications must be in compliance with CAR.

Chapter 2: Labelling

1. Pesticides with labels with no reference to aerial application must not be applied by air.
2. Pesticides with Forest Management - Restricted on the label can be applied to areas greater than 500 ha. Pesticides with Woodland Management - Restricted or Commercial can only be used on wooded areas or areas to be planted with trees up to 500 ha in area.

Chapter 3: Human Health

1. A
2. An enzyme which is necessary for proper nerve functioning.
3. Before using pesticides and when applicator has been exposed to organophosphorous or carbamate insecticides.
4. 120 days

Chapter 4: Safety

Hazards

1. T
2. T
3. Flying the aircraft at near gross weights and low airspeed, operations at low heights, high frequency of takeoffs, long working hours, risk of exposure to toxic chemicals.

Safe Application Procedures

1.	F	4.	T
2.	F	5.	T
3.	T	6.	F

Meteorology

1. Density altitude and low-level wind shear

Flagging Safety

1. T
2. F
3. T
4. T
5. New flaggers should be trained on proper flagging procedures and paired with experienced personnel for orientation; flaggers should keep the aircraft in sight at all times.

Site Selection and Organization

1. F
2. Temporary storage areas must be located on ground that is flat and not highly permeable and away from a watercourse such as a lake or stream or river. The distance will depend on the soil type and topographical situation of the area.

The Mixing and Loading System

1.	T	4.	T
2.	T	5.	F
3.	T	6.	T

Mixing and Loading Responsibilities and Precautions

1.	F	4.	F
2.	T	5.	T
3.	T	6.	F

7. Wear clean and well-fitted goggles or a face shield, respirator if required, rubber gloves; wear coveralls, rubber boots and an apron for protection in the event of a splash or spill; change clothes daily and more often if any contamination occurs; discard leaky gloves or contaminated boots; be certain to read the label of every pesticide used.

Chapter 5: Environment

1.	F	4.	F
2.	F	5.	T
3.	T	6.	T
		7.	T

8. Any four of the following: exposure of workers or bystanders to pesticides, contamination of domestic water supplies, contamination of crops, poisoning of honey bees, contamination of water bodies, elimination of beneficial insects
9. Any four of the following: potential for contamination of water bodies, loss of vegetation canopy over streams, loss of cover for birds, ungulates, carnivores and their prey, loss of forage vegetation, loss of diversity of plant species
10. Do not apply pesticide to waters used for domestic purposes unless allowed on the label; do not apply pesticide to fish habitat identified as non-target areas by local fisheries authorities and take care to prevent their contamination from drift; larvicides should only be applied by air where it is not reasonable to apply them using ground-based equipment to minimize drift

Chapter 6: Pest Management

Integrated Pest Management

1. IPM uses all available techniques. It emphasizes prevention. Treatments are made only when monitoring shows they are necessary.
2. Identification, Monitoring, Action Decisions, Treatments, Evaluation

Pest Biology

1. Annual weeds complete their life cycle within one year.
   Biennial weeds live more than one year but less that two years.
   Perennial weeds are plants that live more that two years.
2. Conifers have needles or scale-like leaves and produce seeds in cones.
   Herbaceous plants are soft stemmed such as grasses, thistles, dandelions, etc.
3. Often herbicides are only effective when crops or weeds are at a certain stage of growth.
4. Insects have six legs, many have wings and range in size from very small to several centimetres in length; mites have eight legs, have no wings and most are less than 1–2 mm in length.
5. the last two larval stages
6. Disease organisms (fungi, bacteria, etc.), insect damage, herbicide damage or environmental stress

7. A disease-causing organism, a host susceptible to the disease, an environment favourable to the disease organism

Pesticide Characteristics

1. Contact herbicide, systemic herbicide
2. Herbicides are generally more effective on young fast growing weeds; perennials often become more resistant to herbicides as they grow older, but may become more susceptible in the bud or early flowering stage.
3. Growth regulators
4. Protectant, eradicant, systemic

Pest Management Considerations by Sector

1. IPM consultants or scouts or provincial pest management specialists
2. Site preparation is the improvement of a site to allow for reforestation; stand tending is improving the survival or growth of seedlings or young forest.
3. Any three of: possible effects on fish and wildlife, possible contamination of drinking water, few herbicides are registered for use, public concern.
4. Budbreak sprays, early foliar sprays, late foliar sprays, fall sprays
5. Woody tissue feeders, defoliators
6. Aerial application is usually not sufficiently selective to encourage desirable vegetation while eliminating undesirable vegetation
7. There are many species of mosquitoes, only a few are a nuisance, it is important to identify where the nuisance ones are breeding
8. Adulticiding should only be used if mosquitoes are a significant nuisance; monitoring is used to determine when there are sufficient numbers to spray.

Chapter 7: Application Technology

Aircraft

1. At low speeds, the helicopter's rotor wake can be used to disperse spray to the undersides of crop leaves.

Aircraft Dispersal Systems and Components

1.	T	10.	F
2.	F	11.	T
3.	T	12.	T
4.	F	13.	T
5.	T	14.	F
6.	T	15.	T
7.	T	16.	F
8.	T	17.	T
9.	T	18.	F
		19.	T

Navigational and Swath Guidance Systems

1.	T	3.	F
2.	T	4.	T
		5.	T

General Considerations and Techniques

1.	F	8.	T
2.	T	9.	F
3.	T	10.	T
4.	T	11.	T
5.	T	12.	F
6.	F	13.	T
7.	T	14.	T

Swath Characteristics

1.	F	8.	F
2.	F	9.	T
3.	F	10.	T
4.	T	11.	T
5.	F	12.	T
6.	T	13.	F
7.	F	14.	T
		15.	T

Spray Characteristics

1.	F	11.	T
2.	T	12.	T
3.	T	13.	F
4.	T	14.	T
5.	F	15.	F
6.	T	16.	F
7.	T	17.	T
8.	F	18.	F
9.	T	19.	T
10.	T	20.	F

21. Moderate temperatures, humidity less than 50%, low wind speed, no temperature inversion
22. Droplet size

Calibration

1.	T	6.	F
2.	F	7.	T
3.	T	8.	T
4.	F	9.	F
5.	T	10.	F

11. no spray area = 220 m × 200 m = 44,000 m^2/10,000 = 4.4 ha
    actual spray area = 84 ha & 4.4 ha = 79.6 ha
    total product required = 7 L/ha × 79.6 ha = 557. 2 L
    total spray required = 36 L/ha × 79.6 ha = 2865.6 L
    total water required = 2865.6 & 557.2 = 2308.4 L

Chapter 8: Emergency Response

1.	T	5.	T
2.	T	6.	F
3.	F	7.	T
4.	F	8.	T
5.	T	9.	T
6.	F	10.	F

GLOSSARY

Aerosol - The suspension of fine particles (liquids or solids) in the air.

Adjuvant - A material added to a spray tank mixture to improve application effectiveness.

Airspeed - The speed of an aircraft relative to the surrounding air. Contrast with Groundspeed.

Ambient conditions - The temperature, relative humidity, etc. of the surrounding air.

Application rate - The total amount of material applied per unit area. Units are expressed as gallons or pounds per acre, or litres or kilograms per hectare.

Atomization - The reduction of a liquid to small particles or a fine spray.

Aural protection - Sound absorbing helmets and/or earplugs to prevent loss of hearing.

Boom - A length of pipe or tubing that extends laterally from an aircraft.

Booms on/off - Opening/Closing the spray valve to begin/end spraying.

Broad-spectrum insecticide - Insecticides which are non-selective and have effective toxicity to many insects.

Brushing - Management of vegetation competing with seedlings or crop trees for light, moisture and nutrients.

Budbreak spray - Herbicide application performed in late winter or early spring when new leaves of target species are just beginning to form.

Buffer zone - An area that is not assumed to be pesticide free, but rather an area that is not directly sprayed with pesticides as part of the target area, and where minimal spray deposits may fall as a result of adjacent spray operations. Buffer zones are designed to prevent the deposit of spray materials onto areas requiring protection. Further, any residues that enter the Buffer zone must not cause unacceptable phytotoxic (i.e., plant damage) or zootoxic (i.e., wildlife poisoning) damage in the Buffer zone. The Buffer zone must not occupy part of an area requiring protection.

Calibration - Measurement and adjustment of the flow rate to ensure a correct application rate.

Carrier - An inert substance that dilutes a pesticide, providing a tank mixture suitable for application. Water and oils are common carriers.

Conifer release - Management of vegetation that is overtopping or surrounding crop seedlings or trees to promote crop growth to a free-to-grow stage.

Contact pesticide - A pesticide that controls a target pest either from direct contact at the time of application, or contact by the pest though residual deposit.

Crosswind - Wind at right angles to the line of flight.

Defoliant - A chemical substance that causes foliage to drop from plants.

Dessicant - A substance that accelerates drying.

Diluent - A component of a dust or spray that dilutes the active ingredient.

Displaced Swath - That portion of the dispersed material that is moved by the wind for relatively short distances and lands within the target area. Contrast with Drift.

Dosage (Dose rate) - The amount of active ingredient applied per unit of area treated.

Downwash - The movement of air forced down by an aircraft in flight as a result of the production of lift by wings or rotors.

Downwind - The direction towards which the wind is blowing.

Drift - The aerial movement of material to non-target areas. Comprised mainly of droplets less than 100 microns VMD. Contrast with Displaced Swath.

Drybreak valve - A coupling used to load liquids, designed so the external portions remain dry after being disconnected.

Early foliar spray - A herbicide application performed in late spring.

Effective swath width - The distance between the two points on each side of the pattern centerline where the material density is approximately ½ that at the center.

Efficacy - The production of a desired effect. Discussions center around spray efficacy (i.e., how well the pest is controlled).

Emulsifier - An adjuvant allowing oil-based pesticides to mix with water.

Emulsion - A suspension of small droplets of one liquid in another.

Entomologist - One who studies insects.

Fall spray - Herbicide application performed between late August to early October.

Flow rate - Is the volume of spray or weight of granules delivered in a specific time period (e.g., L/min, kg/min).

Foaming agent - An adjuvant that produces a thick pesticide foam.

Ferrying - Flight to and from the target area.

Groundspeed - The speed of an aircraft relative to the ground.

Hot refuelling - Refuelling while the engine is running.

Inboard - Locations on a wing or boom close to the fuselage. Compare with Outboard.

Invert emulsifier - An adjuvant allowing water-based pesticides to mix with oil-based carriers.

Inversion - Reversal of normal lapse rate. With inversions, temperatures increase with altitude.

Lapse rate - The rate of decrease in temperature with increases in altitude. Standard lapse rate is 1.9 degrees C. (5.4 degrees F.) per thousand feet.

Larva - The immature stage of certain insects that hatches from the egg stage (e.g., caterpillars that become moths, maggots that become flies).

Late foliar spray - Herbicide application performed mid to late summer.

Leaching - The movement of pesticide through the soil with water.

Leading edge - The forward edge of a wing or rotor.

Lofting - Wingtip/rotortip vortices and the aircraft wake pattern carry small droplets considerably above the aircraft flight path, prolonging exposure of droplets to meteorological factors causing drift.

Micron - 1/1000 millimetre, or 39 millionths of an inch.

Mixing rig - The mixing/loading units.

Number Median Diameter (NMD) - The droplet size dividing a spray cloud into halves containing equal <u>numbers</u> of droplets. Compare with VMD.

Non-target area - Any area that is to remain free of pesticide deposit.

Nozzle - A device used to atomize a liquid, breaking it up into droplets.

Nymph - The immature stage of certain insects and mites that hatches from the egg stage and resembles the adult, but lacks fully developed reproductive organs.

Outboard - Locations on an aircraft wing or boom a distance away from the fuselage. Compare with Inboard.

Output - Refers to the amount of spray mix (for liquids) or the amount of granular pesticide (for solids) applied per unit area (e.g., L/ha, kg/ha).

Payload - The useful size of load carried by an aircraft.

Penetrant - An adjuvant allowing the pesticide to get through the outer layer of a treated surface.

Pointer aircraft - In forestry, a non-spraying aircraft leading the spray team. It is usually positioned several hundred feet above and sufficiently ahead to permit easy visual contact from the tankers. It is responsible for accurate navigation of spray lines in the target area.

Pullup - A positive (but not abrupt) raising of the aircraft's nose at the end of a spray run to initiate the turnaround.

Pupa - The growth stage of certain insects during which the larva (e.g., caterpillar) radically changes shape to become an adult (e.g., moth) with legs, wings, antennae and functional reproductive organs.

Racetrack pattern - An aerial application pattern where the first pass divides the area in half, with the next pass being along the downwind boundary. Passes alternate between the two halves, progressively moving upwind.

Relative humidity - The amount of water in the air at a given temperature, compared as a percentage to the maximum amount of water it could hold at that temperature.

Rooster tail - The lofting of airflow behind a fast-moving aircraft, caused by increasing lift produced by the horizontal stabilizer. Similar to the arc of spray behind hydroplanes.

Rotor - On helicopters, the large horizontally situated blades (main rotor) providing lift and thrust, and the smaller vertically mounted blades (tail rotor) providing directional control.

Rotortip vortices - See Vortex.

Rotary Atomizer - A unit that uses a rapidly spinning wire cylindrical cage to atomize a liquid.

Runoff - The movement of water over the land surface.

Sedimentation - The fall of a droplet or particle after dispersal.

Shuttle pattern - A back and forth application pattern starting at one side of an area and working progressively upwind. Compare with Racetrack pattern.

Spanwise airflow - Lateral movement of air along a wing towards the wingtip.

Spreader - An adjuvant that decreases the surface tension of the spray mixture, allowing the pesticide to form a uniform coating over the target's surface.

Sticker - An adjuvant improving pesticide adherence to plants or other surfaces.

Surface tension - Liquid forces resisting the expansion of the liquid's surface area. Properties are similar to those of an elastic skin under tension.

Swath - The deposition pattern formed by one pass across the treated area.

Swath width - The width of the deposition pattern. See Total, Displaced and Effective Swaths.

Target - The pest to be treated by the pesticide.

Thickener - An adjuvant that thickens a spray mixture. Reduces drift by increasing droplet size.

Total swath width - The maximum distance between the ends of the ground deposit pattern not including drift.

Trailing edge - Rear edge of a wing or rotor.

Turbulence - Unstable and erratic air flow in the atmosphere consisting of horizontal and vertical motions. Primarily caused by wind and heating effects.

Turnaround - A standard turning procedure after a spray run is completed, used to reverse direction 180 degrees and line up for the next run.

Ultra-low-volume (ULV) - Application rates less than 5 litres per hectare.

Upwind - The direction from which the wind is blowing.

Variable Restrictor Unit (VRU) - Controls the flow rate on a Micronair.

Viscosity - A measure of the resistance of a fluid to flow. The thicker the fluid, the higher the viscosity, and the more pressure required to achieve a given flow rate.

Volatility - The tendency of a liquid to evaporate. High volatility means quick evaporation.

Volume median diameter (VMD) - The droplet size dividing a spray cloud into halves containing equal volumes of liquid. Compare to NMD.

Vortex (Vortices) - The whirling air pattern produced by airflow from wing-, propeller-, or rotor-tips. Resembles eddies or whirlpools in water.

Walk-around - External check of aircraft and dispersal gear before flight.

Wingtip vortices - See Vortex.