EQUIPMENT PESTICIDE TRAINING MANUAL

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DEPARTMENT OF AGRICULTURE
ENVIRONMENTAL MANAGEMENT DIVISION
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PREFACE

This manual contains a basic description of the types of ground and aerial pesticide application equipment, its maintenance, safe use, and calibration. The manual is intended as a study guide for all applicators being licensed to apply restricted use pesticides. It can also serve as a reference for future maintenance, use, and choice of appropriate equipment.

The selection of proper application equipment, its maintenance and safe use, and calibration are essential for obtaining effective results from pesticide applications. This manual will illustrate, for example, the types of equipment appropriate for various crops and pests. It will outline the types of equipment components that are most suitable for the various mixes or formulations of pesticides. These and other topics may assist many applicators in efficiently using their equipment. Hopefully, applicators will continue to follow the suggestions of this manual. They will improve pest control and protect environmental and human health.

To simplify information, trade named products and equipment have been mentioned. No endorsement is intended, nor is criticism implied of similar products or equipment which are not mentioned.

We wish to acknowledge the help of personnel of the Environmental Management Division, Montana Department of Agriculture, in preparing this manual.

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CHAPTER I

PESTICIDE FORMULATIONS AND COMPATIBILITY

The choice of a pesticide depends, in part, upon the equipment the applicator has available. Many applicators own boom sprayers that are sufficient for a variety of liquid pesticides. Many products such as dry dusts or liquids intended for atomizers need specialized equipment. Pesticide selection depends upon a number of principles; one of these is the formulation or the manner in which the active ingredient, carrier, and special additives are mixed. The following chapter is a discussion of these pesticide components.

A. Formulations

Formulations affect the physical state of the pesticide and the method of application. Following are some common types of formulations:

1. Dusts are a mixture of the active ingredient with a carrier such as talc or clay. Fine particle size makes dust formulations susceptible to drift. Forced air is often used to deliver dusts. Herbicides seldom are marketed as dusts because of associated drift problems.

2. Granular formulations are formed by impregnating an active ingredient on a small particle (1-2 mm. diameter) of carrier. Granules are used to penetrate dense foliage. Granules usually are marketed ready to use. Where residual action is required, they may provide slow release of pesticide.

3. Wettable powders are dry pesticides that have been attached to a dry carrier such as clay. A wetting agent is usually added and the powder is mixed with water to form a suspension that must be kept agitated in the spray tank. A sticker or adhesive agent is usually added to promote adhesion.

4. Emulsifiable concentrates contain a pesticide and an emulsifying agent in a solvent such as xylene or petroleum fractions. These are diluted with water to form an emulsion that can be applied as a spray.

Emulsions can occur in two ways depending on the mixing:

a. Normal emulsions consist of the oil phase or concentrate dispersed in water.

b. Invert emulsions are prepared by adding the oil phase to the water phase. The oil phase then becomes continuous, surrounds cells of water, and evaporation is reduced.

Emulsions usually form with very little agitation and should be stable for about a day.

5. Oil Solutions - Most pesticides are not soluble in water so petroleum oils are commonly used as a solvent. Examples of oil solvents are deodorized kerosene, fuel oil, and xylene. Oil solutions are generally avoided for use on plants; however, they can be sprayed in mist blowers where the oil evaporates before reaching the plants.

6. Concentrates or Ultra Low Volume (ULV) formulations are applied with ULV applicators. The active ingredient is applied in its concentrated form. Evaporation is reduced because water is absent. ULV droplets are of greater density than those in water based sprays, thus increasing their rate of fall. Because less volume of formulation is applied per acre, more acreage can be treated before reloading.

7. Baits consist of the active ingredient mixed with a solid carrier that is attractive to the pest, such as rolled oats or sugar. Rodenticides are usually dispensed in bait form.

8. Flowables or suspensions are liquid or viscous concentrates of a suspendible pesticide in water as minute solid particles. Flowables usually require further dilution and must be kept agitated.

9. Fumigants are usually liquids that, when exposed to warm air or released from pressure, form a toxic gas, fume, or vapor. They are usually used in air tight enclosures or confined spaces such as grain bins, buildings, greenhouses, or rodent burrows. Some soil fumigants are produced in granular form.

10. Aerosols consist of small particles, about 10 microns, suspended in air and are often used in adult mosquito control and in structural pest control. Because of a tendency to drift, they are not useful in most agricultural situations. Aerosols are produced by the following methods:

a. forcing a liquid under pressure through atomizing nozzles,

b. release of liquified gas through expansion chamber or capillary nozzles,

c. steam or air atomization of a liquid,

d. heat vaporization,

e. spinning discs or rotors.

11. Fogs and mists are produced by methods similar to aerosols but particles are smaller, about one-tenth micron. They have been used in mosquito control and in treating confined spaces.

12. Capsules made of materials such as gelatin may confine the pesticide and dissolve or disintegrate to release the pesticide.

B. Accessory Materials and Adjuvants

The mode of action of pesticides may be improved by the addition of accessory materials and adjuvants. Accessory materials include diluents, carriers, solvents, and adjuvants.

1. Carriers are added to concentrates and give the formulation "body" and "surface" adequate for application. Carriers are often inert ingredients such as water in flowables or talc in dusts.

2. Diluents are liquids added to reduce the concentration to the appropriate application rate.

3. Solvents are used to dissolve a formulation into a carrier or diluent; they are usually utilized when the formulations are solid or viscous. Diluents and carriers may also act as solvents.

4. Adjuvants are added to pesticide formulations to improve their mode of action. These substances may increase spreading properties, assist emulsification, enforce toxicity, promote penetration of plant parts, reduce interfacial tensions, and perform other related functions. Adjuvants are either incorporated into the pesticide formulation at the time of manufacture or added by the applicator under certain restricted conditions. The addition of proper adjuvants can result in a more effective and economical pesticide. Following is a description of the various types of adjuvants and their properties.

a. Surfactants or Spreading Agents allow the pesticide to "spread out" over treated surfaces and assist in "wetting" dusty, waxy, or greasy surfaces. These materials also reduce surface tension allowing the pesticide to make contact with a solid surface and lend to penetration of the chemical into plants and animals. Caution should be exercised because surfactants may destroy protective wax layers on leaves or fruits and damage the crop.

b. Emulsifiers or Emulsifying Agents are utilized to maintain the stability of an emulsion. Stability of a mixture relates to the length of time it stays mixed. Oil and water mixtures separate readily; the addition of an emulsifier stabilizes the mixture because it occupies the space between the oil and water. Soaps and detergents may serve as emulsifiers. Detergents are usually preferred because soaps form alkaline solutions with water.

c. Sticking or Thickening Agents improve spray adherence to surfaces such as leaves. Thickening agents increase viscosity and increase spray adherence to leaves thus reducing spray bounce and run-off during spraying. The term "spreader-sticker" is commonly utilized today. Sticking agents are usually added to formulations to reduce the amount of run-off from surfaces caused by spreading or wetting agents.

Other types of adjuvants include antisticking agents, penetration agents, dispersing agents, bridging agents, and activators or synergists.

C. Compatibility of Pesticides

Application of one pesticide at a time has been the common agricultural practice. Today, because of the high cost of application, pesticide applicators have begun mixing pesticides in an attempt to control several pests with a single application.

When two or more pesticides can be mixed together without any adverse changes in action or structure, they are compatible. Certain pesticides, however, are incompatible because adverse changes occur between the active ingredients or formulations. Several reasons for incompatibility are given below:

1. Physical incompatibility is difficult to evaluate and is often caused by the additives rather than the pesticides being incompatible. The results of physical compatibilities are varied. A common one is the formation of precipitates in the mixture that can plug screens and nozzles. Another occurs when the activity of an emulsifier is stopped. Mixtures may then separate or form large droplets within the tank.

2. Chemical incompatibility occurs when chemical reactions occur that destroy the effectiveness of one or more pesticides. For example, fungicides or adjuvants that are strongly alkaline may decompose synthetic organic insecticides and change their activity. Precipitates may occur that will plug screens and spray nozzles. Formulations may be altered so that they no longer contact or adhere to the target. Reactions may occur which cause the formulation to be toxic to plants or phytotoxic. Chemical incompatibilities cannot always be recognized in the spray tank.

3. Timing incompatibility - Pesticides must be applied at the most susceptible development stage of the pest for greatest effectiveness. When spraying a mixture of two or more chemicals, it may be difficult to time the application to the most susceptible stage of the various pests.

4. Water incompatibility - Water is the most common carrier for pesticides. Water hardness (high amounts of calcium) may alter the formulation of a pesticide, making application difficult or less effective. Generally, waters that are "soft" should be utilized as carriers. Applicators should determine the hardness of water in their area prior to mixing one or more pesticides. Water may be softened chemically, thus preventing problems in mixing pesticides.

Points to Consider When Mixing Chemicals

(1) The compatibility of the various chemicals must be known before the materials are combined.

(2) As a general rule, do not mix herbicides with insecticides.

(3) Follow all label directions carefully. The use of tank mixes not specifically stated on the label is discouraged by most manufacturers.

(4) Combinations containing lime or having a high alkalinity are harmful to synthetic organic chemicals. Most organophosphates and carbamates are subject to alkaline decomposition.

(5) The use of oils and petroleum solvents in combination with organic chemicals may increase phytotoxicity.

(6) Most of the dinitro miticides may become phytotoxic if mixed with oil.

(7) Organophosphates combined with dinitros may cause burning of foliage.

(8) Consult all available sources before utilizing combinations.

Compatibilities of various chemicals can be checked by referring to a compatibility chart in the Farm Chemicals Handbook. Some chemical companies also print compatibility charts.

Caution is imperative to any applicators wishing to check unknown compatibilities. Chemical or phytotoxic compatibilities cannot be observed. Keeping the above eight points in mind, physical compatibilities can be checked by mixing small amounts of chemicals in jars. These mixtures should be observed initially and after one hour for any adverse changes such as settling, precipitates, gumminess, separation, etc.

Pesticide labels will often list compatible and incompatible chemicals. If not, it is permissible by the Federal Insecticide, Fungicide, and Rodenticide Act to mix pesticides or pesticides and fertilizers. This should be done with caution. Contact the Montana Department of Agriculture Pesticide Specialist in your area for assistance.

D. Synergism

When the effect of two combined chemicals in greater than the effect of either compound alone, the result is called synergism. Utilizing two products with synergistic qualities may increase the effectiveness of the treatment; however, the use of a synergized compound may also increase the problem of toxicity to mammals.

CHAPTER II

GROUND EQUIPMENT, ACCESSORIES, AND MAINTENANCE

A. Types of Ground Equipment

The five basic classes of ground application equipment include hydraulic sprayers, air sprayers, foggers and aerosol generators, power dusters, and hand held equipment.

1. In hydraulic sprayers, pesticide is delivered under pressure by a pump to one or more nozzles. The kind of nozzle regulates droplet size and spray pattern. The components of a typical low-pressure, low-volume hydraulic sprayer are shown in figure 1. Hydraulic sprayers are of 4 basic types:

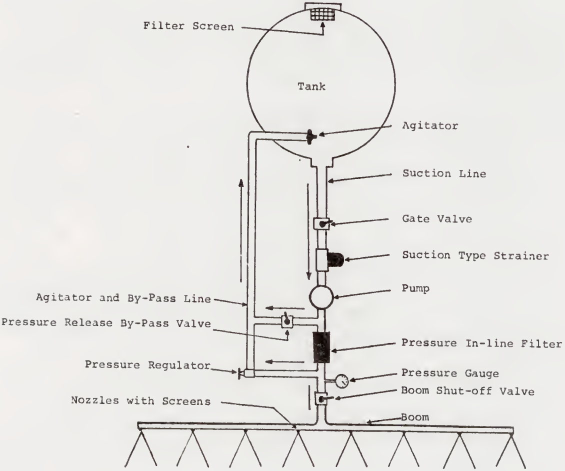
   a. Multiple-purpose sprayers provide versatility for a variety of farm problems. Spray pressure is adjustable and can provide, for example, 40 pounds for weeds or 400 pounds or more for spraying fruit trees. Tank size ranges from 50 to 200 gallons. Sprayers are skid or wheel mounted and powered by auxilary engines or a power take-off. Spray is dispensed through a hand gun or field boom.

   b. Small general use sprayers are useful for small spraying jobs that are too large for hand equipment. They are useful in greenhouses, large gardens, and golf courses. Tank capacities vary up to 25 gallons. Power is from a 1/2 to 2 horsepower engine that provides a wide range of pressures (50-500) psi). Spray is dispensed through a hand gun or short boom. Sprayers are usually mounted on a hand-operated cart; some can be attached to a garden tractor.

   c. Low-pressure, low-volume sprayers are commonly used in Montana crops. They can be mounted directly on equipment or are equipped with wheels. Sprayer tanks hold up to 250 gallons. Power is usually from the tractor pto but may be supplied by an auxiliary engine. Operating pressure is up to 100 pounds and spray is dispensed through a field boom. Some sprayers, the Spray Coupe for example, are self-propelled.

   d. High-pressure, high-volume sprayers are used by fruit growers and truck farmers in order to obtain good penetration and coverage in tall growing trees and dense crop growths. These sprayers are essentially the same as multiple-purpose sprayers except that larger engines provide up to 1000 pounds of pressure. Tank sizes are also larger and range up to 600 gallons.

Figure 1. Components of a Boom Type Field Sprayer with Hydraulic Agitation.



2. <u>Air sprayers</u> (also known as ultra-low volume, concentrate blower, air-blast, and air-mist sprayers) are used for spraying orchards, large shade trees, and field crops. Pesticides are applied in concentrated form using relatively small volumes of water in contrast to hydraulic sprayers. Labor involved in loading is saved and pesticide runoff is reduced. A low-volume pump delivers the liquid spray under low pressure to the fan where it is discharged into an air stream in small droplets by a group of nozzles or shear plates. Pump pressures range from 50 to 400 p.s.i. and fans deliver from 5000 to 25,000 c.f.m. or air velocities of 100 to 150 m.p.h.

3. <u>Foggers or Aerosol Generators</u> are designed primarily for control of mosquitoes and flies in large buildings, parks, resorts, or communities. These machines disperse fine particles of pesticides into air, as fogs or mists, where they remain for a considerable time period. Fogs and aerosols are produced by either thermal (heat) or mechanical methods or a combination of both.

Air currents assist in moving the pesticide to the target area, taking advantage of the principle of air inversions. Applications are usually made at night when wind, temperatures and humidity conditions are optimum.

Aerosol equipment is not practical for most agricultural pesticide applications (especially herbicides) because of their tendency to create drift problems.

4. <u>Power dusters</u> are powered by engine or power take-offs. Like air blast sprayers, dusters also utilize air streams from a centrifugal fan to carry the pesticide to the target area. They may have single or multiple outlets. Dusters may be impractical for application of some pesticides, especially herbicides, because of drift hazard.

5. <u>Hand application equipment</u> is designed primarily for application of pesticides in small areas like homes, gardens, businesses, or yards. This type of equipment includes hand pump atomizers, aerosol dispensers, compressed air sprayers, knapsack sprayers and dusters.

a. The <u>hand pump atomizer</u> uses a hand operated pump to force an air stream over the tip of a siphon tube. Pesticide is sucked from the tube and atomized in the air stream. The intermittent type sprayer produces a spray only on the forward motion of the pump. The continuous sprayer delivers a continuous spray because pressure is produced in the tank. These sprayers are commonly used to control flying insects in the home. They have nearly been replaced now by aerosol dispensers.

b. Aerosol dispensers or "bug bombs" are probably the most common type of applicator. The pesticide and a propellant, usually freon, are forced, under pressure, through an atomizing nozzle. Many household pest sprays are dispensed in aerosol bug bombs.

c. Compressed air sprayers are designed to hold 1 to 3 gallons in the tank. A hand pump is used to pressurize the tank and to deliver the pesticide, under pressure, to the nozzle. Spray patterns and droplet size can be regulated by nozzle type. Solutions, emulsions, or suspensions of pesticides can be utilized at pressure of 30 to 50 psi. The use of CO_2 cylinders in place of the hand pump may be utilized to achieve the correct pressure.

d. Knapsack hand sprayers are carried on the back and usually have a capacity of 5 gallons. A hand operated piston or diaphragm pump provide the pressure (30 to 100 psi) to expel the pesticide.

e. Duster hand sprayers range from small self-contained units to those mounted in wheelbarrows. Air velocity for dispensing the dust is created by a plunger, hand crank, or belt attached to a fan or blower.

Additional types of hand sprayers include bucket, barrel, and wheelbarrow sprayers utilized for spraying larger areas or trees and hose sprayers in which a jar container is attached to a garden hose.

B. Accessory Equipment

Sprayer accessory equipment consists of nozzles, pumps, pressure regulators, strainers and screens, nozzle check valves, agitators, pressure gauges, and tanks.

1. Nozzles are manufactured with a variety of functions and for many conditions. Performance tables are available from most dealers.

Types of Nozzles

There are many types of nozzles used in spraying. Each have different purposes and differ in such factors as spray pattern, flow rate, and average droplet size. Some of the common nozzles are illustrated in Figure 2 and discussed below.

a. Flat Fan Nozzles produce a fan-shaped spray pattern with tapered ends and a fan angle of 65 to 80 degrees. The tapered ends permit overlapping of spray patterns to assure uniform coverage. Adjacent spray patterns should not be allowed to impinge on each other because it will destroy the uniformity of coverage. Each spray nozzle should be rotated approximately 12 - 15 degrees from the line of the boom so the patterns are slightly offset (Figure 3). Flat spray nozzles are generally used in surface spraying in agriculture and many other types of pest control. They do not provide very good foliar penetration.

b. Even Fan Nozzles deliver a uniform fan-shaped pattern with a fan angle of 80 degrees. Edges of the pattern do not taper as in flat spray nozzles. These nozzles are used for band or row application, pre-emergence or early post-emergence. Broadcast applications are not recommended because of the difficulty of preventing overlap (overdose) or gape between spray patterns. Like flat spray nozzles, they do not provide good foliar penetration.

c. Flooding Fan Nozzles provide a flat spray pattern with a wide spray angle (100 - 145 degrees). These nozzles produce a wide spray pattern and large droplets at low pressure. Because of the nozzles' wide spray angle, they can be widely spaced on the boom and carried close to the ground to reduce drift. If these nozzles are angled 10 to 15 degrees in the direction of travel, drift can be further reduced. These nozzles can be used in general broadcast application of fertilizers, herbicides, and defoliants. They are commonly used for applying materials which require soil incorporation. They do not provide good foliar penetration.

d. Cone Spray (Solid or Hollow) Nozzles deliver a cone shaped spray pattern which may be solid or hollow depending on the nozzle's design. These nozzles are generally used at high pressure to deliver insecticides and fungicides to row crops and provide good foliar penetration. Because these nozzles produce smaller droplets, the potential for drift is increased.

e. Off Center Flat Fan Nozzles produce a one-sided flat spray pattern which is used on the end of a boom to extend coverage by 5 feet.

f. Twin Orifice Flat Fan Nozzles are used to apply herbicides between row crops. Nozzles produce a wide, fan-shaped pattern which can be applied close to ground level.

g. Multiple-Orifice Nozzles or clusters of nozzles are used in place of a boom and spray a swath 30 to 50 feet wide. These nozzles are used to spray roadsides,

Figure 2. Types of Nozzles

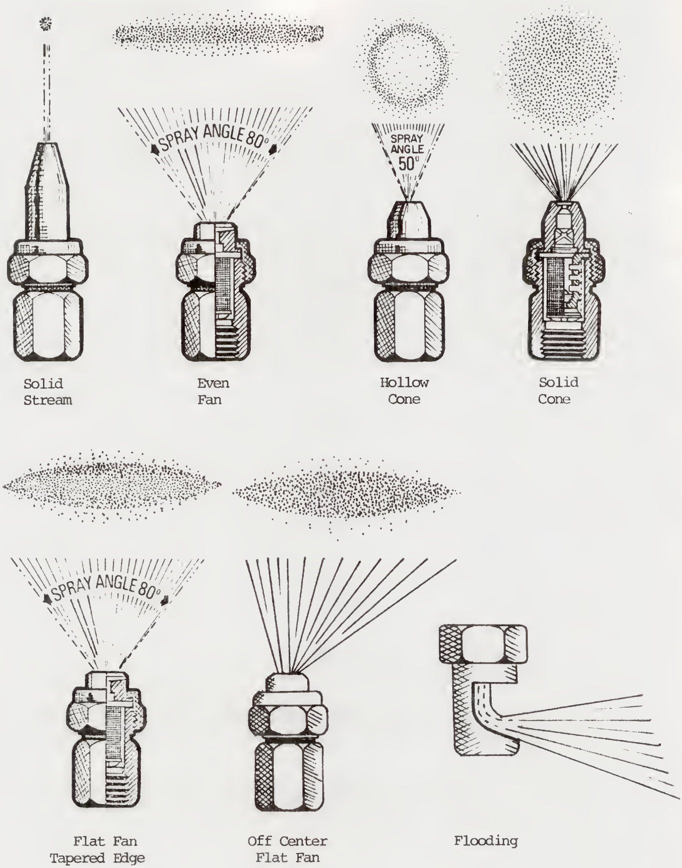
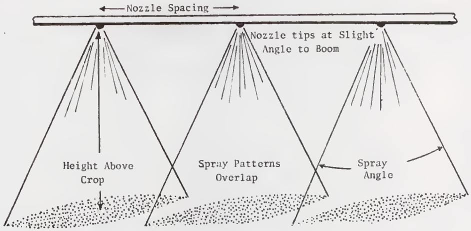


Figure 3. Section of a field boom showing proper alignment of fan nozzles to provide spray overlap.



ditchbanks, or other places where a boom or field sprayer is not satisfactory. The spray pattern is easily affected by wind conditions which may cause poor coverage and pesticide drift.

h. Low-Pressure and Reduced Pressure Nozzles are designed to reduce the potential for spray drift by producing larger droplets.

(1) Low-Pressure Nozzles operate in the 10 to 30 psi range and provide the same spray angle and flow rate as a conventional nozzle at 40 psi. Because the nozzles operate at lower pressures, they wear longer and there is less stress on other sprayer components.

(2) Reduced Pressure Nozzles operate at the standard pressures but, because of their design, there is a pressure drop within the nozzle. The net result is that fewer droplets smaller than 100 micrometers are produced. Nozzles of this type work best for applying high volume, for applying materials that require soil incorporation, or where fine coverage is not necessary. These nozzles may not be adequate with low volume application or foliar application where complete coverage is required.

i. Straight Stream Nozzles are simple nozzles with a center orifice that produces a straight stream of liquid. These nozzles are used for subsurface application of liquid fertilizers, soil fumigants, and some aquatic herbicides, and for crack and crevice treatment in structural pest control.

Nozzle Materials

Nozzle tips are made from a variety of materials varying in cost and resistance to wear and corrosion. The following are some common materials listed in order of resistance.

a. Nylon or Plastic is suitable for most pesticides, resists corrosion and wear, but may swell when exposed to some solvents.

b. Brass resists corrosion but wears quickly from abrasive materials; brass nozzles are for limited or short term use and are inexpensive.

c. Aluminum is not recommended for abrasive materials such as wettable powders and can be corroded by some fertilizers but is inexpensive.

d. Stainless Steel is suitable for all formulations, all purpose use; resists corrosion and wear and is expensive.

e. Tungsten Carbide Steel and Ceramic nozzles are extremely resistant to corrosion and wear and are expensive.

Nozzle Numbering and Coding

Unfortunately there is not a uniform system of nozzle numbering. Each manufacturer will indicate flow rate, spray angle, and other information by number and letter codes. Flow rates are measured in gallons per minute (GPM) at a standard pressure of 40 psi using water. For further reference, nozzle manufacturers' catalogs and bulletins provide an excellent source of information.

Disc for Handguns

The spray or cap number represents the diameter of the orifice in increments of 1/64 of an inch. For example, No. 3 disc has an orifice 3/64 inch in diameter. Larger orifices deliver coarser droplets at higher rates. To determine the proper disc size for your operation, consult manufacturers' charts.

Nozzle Flow Rate or Capacity

The flow rate of a nozzle is increased by larger metering passages and exit orifices. Flow rate is also affected in varying degrees by pressure, liquid density, and liquid viscosity.

a. Flow rate varies in proportion to the square root of the pressure. As pressure increases, so does pesticide flow rate.

b. As the pesticide density becomes greater, flow rate is reduced.

c. Effects of viscosity on flow rate are complex, but generally, flow rate decreases as liquids become more viscous.

Many applicators may not be interested in the above factors but they should be aware of their effects on flow rate. They illustrate the importance of calibrating when changing nozzle size, pressure, or spray mixture.

Spray Angle and Pattern

Pressure and liquid viscosity influence spray angle and pattern:

a. Pressure - A minimum pressure is required to develop a proper spray pattern, usually 10 to 15 psi. Lower pressures tend to produce a distorted spray pattern. When pressure is too great, the nozzle will begin to atomize the spray and the pattern will be changed. Applicators can make the mistake of operating at excessive pressures in order to make the spray reach further. Actually the opposite effect may occur as the spray atomizes and pattern changes and drift may occur. A nozzle with a larger orifice should be used.

b. Liquid Viscosity - Viscosity is the only liquid property that has a significant effect on spray patterns. An increase in viscosity produces a narrower pattern and smaller spray angle. At very high viscosities, the spray may become a straight stream.

Atomization & Droplet Size

The range of droplet size is affected primarily by the nozzle orifice size and pressure. Each nozzle produces a variety of droplet sizes, the majority centered around one size. Droplets are measured in micrometers or microns where 25,400 micrometers equal one inch. VMD or Volume Mean Diameter is also used as measure of droplet size. VMD is that droplet diameter whose volume if multiplied by the number of droplets will equal the total volume of the sample. To give an idea of droplet sizes, the following chart is included.

Category	Size Range in Micrometers
Fog	0.1 - 50
Aerosol	1.0 - 50
Mist	50 - 100
Fine Spray	100 - 400
Coarse Spray	greater than 400

Droplet size is influenced by:

a. Nozzle rating and design is the primary factor influencing droplet size. As nozzle capacity and metering passages increase in size, the average droplet generally becomes larger. Spray angle ratings also affect droplet size. Wider spray angles are associated with finer droplets.

b. Pressure - As pressure increases, more droplets of a smaller size tend to be produced. A limit is eventually reached where increasing pressure has little effect in reducing droplet size.

c. Liquid Viscosity - As viscosity of a fluid increases, droplets become coarser. Increases in pressure will counteract the effects of viscosity.

d. Surface tension - Liquids with a higher surface tension are more difficult to atomize. The effect of surface tension is generally minor compared to viscosity.

2. Pumps

The sprayer pump is the heart of the system. Pumps vary in capacity (output), operating speed and pressure, and resistance to corrosion and wear. Capacity, which is affected by speed and pressure should be large enough for high application rates. Pumps should provide for agitation if the sprayer does not have a mechanical agitator.

Manufacturer's performance tables can assist you in selecting the proper pump. Some of the commonly used pumps are:

a. Centrifugal pumps commonly operate from a PTO and must be operated at high speed (3000 to 6000 rpm) to obtain adequate capacity. High output occurs at normal operating pressures (30-90 psi). They are not self-priming and must be located below the fluid level if a priming system is not used. They are resistant to wear and can pump wettable powders or other abrasives.

In operation, liquid enters at the center of a rotating impeller with vanes molded in a spiral configuration. Liquid is forced along the vanes by centrifugal force and out a discharge hose.

b. Turbine pumps exhibit the same advantages and disadvantages as centrifugal pumps. The primary differences are in closer tolerances and additional fins. The optimum operating speed is 1000 RPM and can be directly from a 1000 RPM PTO shaft. A step-up drive is necessary for a 540 RPM PTO shaft. The impeller, nylon or cast iron, is a construction of many closely aligned turbine blades. The housing constricts around the blades at the exit port which forces the liquid from the pump.

c. Roller pumps are inexpensive, short-life pumps useful in a variety of situations. Operating pressure varies from 30 to 200 psi and outputs are up to 50 GPM. Higher pressures and operating speeds decrease pump life. These pumps are suitable for wettable powders but their abrasive nature shortens the pump life. The number of rollers varies from 4 to 8 depending on pump capacity. They are constructed of nylon, rubber, teflon or polypropylene plastic. In operation, a slotted rotor holds cylinder shaped rollers in an eccentric housing. As the rotor spins, the rollers are held against the housing by centrifugal force. Fluid is drawn into the entry port and held in the spaces between the rollers and the housing. At the exit port, the smaller space between the rotor and housing forces liquid into the exit port.

d. Piston pumps - Although they may be operated at low pressure, piston pumps are designed to operate at high pressures. For most agricultural uses, 500 to 600 psi is normal although some pumps may produce up to 1000 psi. Output is nearly proportional to pump speed which, depending on the pump design, may vary from 300 to 1800 RPM. Output from piston pumps is low varying from maximums of 3 GPM to 25 GPM depending on size, number of pistons, and operating speed. When spraying with pressures of 100 psi or more, a piston pump will provide the best long-term reliability. Most high pressure sprayers designed for such uses as ornamental tree spraying, livestock spraying or washing equipment are equipped with piston pumps. Piston pumps are expensive but well constructed and a long service life can be expected. They stand up to abrasive materials and worn parts can be replaced.

Piston pumps are driven by a PTO or auxiliary engine. An eccentric camshaft moves the piston and fluid enters and is forced from one way valves in the piston housing. To smooth the pulsating discharge of liquid, a surge tank or pulsation damper is required.

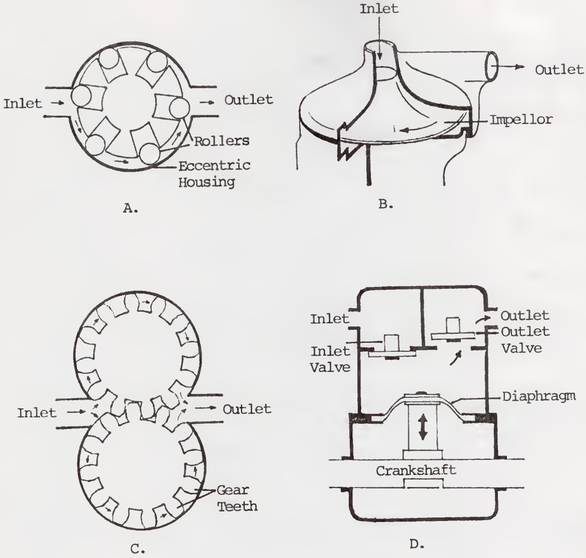
e. The following three pumps see little current use on agricultural sprayers.

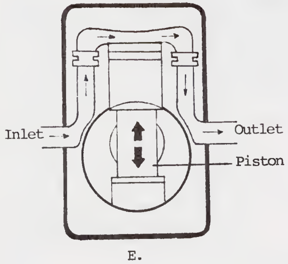
(1) Gear pumps - These pumps incur a high wear rate, and cannot be reconditioned, and must be discarded after they are worn.

(2) Diaphragm pumps - The pumping action in a diaphragm pump is produced by the movement of a flexible diaphragm. Liquid is drawn into one chamber on the downstroke and forced out of another on the upstroke. The diaphragm is resistant to wear by abrasives but may be attacked by certain chemicals.

(3) Flexible Impeller pumps - These pumps have a series of rubber vanes attached to a rotating hub. The pump housing squeezes the hub as the rotor turns forcing the liquid from the exit port. Since the paddles will not return to the extended position if the pressure is too high, a pressure

Figure 4. Diagrams of some pumps used in pesticide application equipment.





A. Roller Pump
B. Centrifugal Pump
C. Gear Pump
D. Diaphragm Pump
E. Piston Pump

relief valve is not needed. They are inexpensive and the rotors are easily replaced. They are not suitable for abrasives but work well as low pressure transfer pumps.

3. Pressure Regulators

a. Pressure Relief Valves maintain a constant pressure to the nozzles despite variations in engine speed. This spring loaded valve allows excess fluid to be bypassed into the tank and, when the boom is shut off, the entire pump output is routed to the tank. These valves are used with roller and piston pumps.

b. Unloader Valves are recommended for high pressure situations as with piston pumps. When pressure becomes greater than the pressure setting, excess fluid is rerouted to the tank. Each time the nozzles are shut off, the unloader valve opens and routes the pesticide to the tank. Line pressure between the unloader valve and the nozzle(s) remains at operating pressure allowing immediate use when spraying is resumed. The pressure of the liquid flowing through the unloader valve back to the tank is very low, saving fuel and pump wear. Some unloader valves, when properly adjusted, can serve as a partial relief by-pass valve.

c. Throttling Valves (manually controlled) distribute and/or restrict the excess pump output. By opening or closing the throttling valve(s) in a spray system, pressure is decreased or increased. Throttling valves are used with centrifugal and turbine pumps.

4. Strainers and Screens

Screens and strainers remove foreign materials that might clog nozzles, wear pumps, or interfere with valves. Screens mesh size refers to the number of openings per linear inch. The higher the mesh size number, the finer the screen.

a. Tank Screens are coarse screens that remove lumps from unmixed material and other large foreign materials when the tank is filled.

b. Line Strainers are generally placed between the tank and the pump. They are an intermediate size, 10-80 mesh, and are necessary to prevent rust, scale, sand, or other small particles from entering and damaging the pump.

c. Nozzle Screens fit inside the nozzle body and provide final screening of the liquid to protect the nozzle tips from plugging. Screens are commonly made of stainless steel or brass and have a mesh size smaller than the nozzle aperture. When spraying wettable powders, slotted strainers are recommended to prevent the buildup of suspended solids.

Screens and strainers must be cleaned often using a soft brush or compressed air. Clogged screens will cause erratic spray patterns, improper metering and delivery, or complete liquid blockage.

CAUTION: DO NOT CLEAN SCREENS OR NOZZLES WITH YOUR BREATH. YOU WILL GET PESTICIDE INTO YOUR MOUTH, NOSE, EYES AND ON YOUR FACE. THESE AREAS ARE HIGHLY RECEPTIVE TO PESTICIDE ABSORPTION.

5. <u>Nozzle Check Valves</u>

When boom control valves or the spray pump are stopped, the liquid remaining in the boom or hose lines will continue to drip from the nozzle and may cause crop damage. This undesirable dripping of spray material can be avoided by the use of nozzle check valves. When the line pressure drops below a certain low pressure, the valve automatically shuts off all flow. The boom remains full, pressurized, and ready for immediate resumption of spraying.

6. <u>Agitators</u>

Many pesticide products, particularly wettable powders and emulsions, require agitation to assure continuous mixing of the pesticide formulation. Agitation can be accomplished by manual, mechanical, or hydraulic methods.

a. <u>Manual Agitation</u> by means of continuous shaking is sufficient for small hand held sprayers but impractical for large equipment.

b. <u>Mechanical Agitation</u> is provided by a series of propellers or paddles mounted on a shaft near the bottom of the tank. Rotation speed is slow (100 to 200 RPM) because excessive agitator speed can cause foaming in some spray mixtures.

c. <u>Hydraulic Agitation</u> is provided by returning a portion of the pump output to the tank. One method discharges the by-pass spray mixture through holes in a pipe located at the bottom of the tank. A second method uses agitator nozzles using the Venturi principle. By-pass liquid flows through the nozzles drawing additional fluid into the moving stream through openings in the side of the nozzle. The volume of liquid for agitation can be increased 2 - 3 times by this method.

Some sprayers have a by-pass or overflow hose returning to the tank from which the spray liquid enters as an unrestricted straight stream. Although this provides circulation and mixing of the tank's spray mixture, it is generally not sufficient to maintain an adequate suspension of the pesticide product.

7. Pressure Gauges

Pressure gauges should be periodically checked for accuracy and should register within the range of pressures commonly used. Properly operating pressure gauges help insure proper application rates, keep drift to a minimum, and reduce equipment wear caused by unnecessary high pressures.

It is common for pressure to be lower at the nozzles than that registered on the gauge. Pesticides moving through hoses, valves, couplings, and screens encounter resistance and pressure is lowered. To reduce pressure loss, hoses should be kept as short and as large in diameter as possible. Fittings should be kept to a minimum. Lines, nozzles, and screens should be cleaned often.

8. Sprayer tanks

Sprayer tanks should have a large opening at the top that is splash proof and equipped with a coarse screen. The cover should be vented and sealed against dust. A drain plug should be located in the tank bottom. Corners should be round to facilitate agitation and cleaning.

Construction materials vary in durability and ability to withstand corrosion. The following are some common materials:

a. Galvanized Steel Tanks give reasonable service if properly cared for but may eventually corrode. They are suitable for most pesticides but corrosive fertilizers and pesticides should be avoided. An epoxy lining will protect steel tanks from corrosion but is not effective against hydrocarbons such as Lasso or Ramrod, or volatile chemicals under pressure.

b. Polyethylene Tanks are lightweight and resistant to corrosive chemicals except for ammonium phosphate solutions and some liquid fertilizers. Polyethylene tanks must be replaced if cracked, broken or punctured. Polyethylene breaks down under ultra-violet light and should be kept covered when not in use.

c. Aluminum Tanks resist corrosion by most chemicals. They should not be used with solutions containing phosphoric acid.

d. Fiberglass Tanks are widely used on agricultural sprayers and are resistant to most chemicals but may be affected by some solvents. Fiberglass is a lightweight but durable material that can be repaired if cracked or broken.

e. Stainless Steel is the highest quality material for spray tanks. It is strong, durable and resistant to corrosion by any pesticide or fertilizer. It is recommended for equipment with a high annual use.

The capacity of the tank will depend upon the size of fields to be sprayed, application rate, boom size, and soil conditions. Excessively large tanks require expensive supports and may compact soil or leave ruts.

CHAPTER III

MAINTENANCE OF GROUND EQUIPMENT

Care and maintenance of equipment will give the best results from your applications and insure the safe use of pesticides. Improperly maintained sprayers can result in:

- Costly repairs
- Improper application rates
- Pesticide spills
- Other pesticide accidents
- Down time

Most dealers provide information and manuals for the care of their equipment but the following chapter gives a brief summary on equipment care.

A. Inspection and Filling

Before use, examine the sprayer carefully for worn parts. Are the hoses cracked and leaking? Examine the suction hose carefully; any leaks will seriously interfere with the pump operation. Examine the boom struts carefully and adjust the boom to the proper height. Clean all components carefully and pay attention to screens, filters, hoses, and nozzles. Any dirt in these parts will interfere with application rates.

Mix chemicals using only clean water. Dirt will plug screens and damage the pump. Water from a ditch or reservoir should be strained.

B. Cleaning the Sprayer

Rinsing the sprayer after use will reduce corrosion and prevent contamination of the next spray and accumulations on sprayer parts. Several rinsing solutions can be used depending on the carrier:

1) Water and ammonia

2) Water and soap or detergent

3) Water and lye (lye is corrosive to aluminum)

4) Solvents

Choose cleaning areas with care so that pesticides are not rinsed onto lawns, children's play areas, or drinking water. Rinse your tanks in areas where humans, animals, or crops will not be exposed. Pesticides should not be flushed into sewage systems without first contacting the Department of Health and Environmental Sciences or the Montana Department of Agriculture, Environmental Management Division.

The following is a suggested procedure for cleaning equipment prior to storage at the end of the season:

Step 1. Hose down the inside of tank completely, fill to half full and flush the system by operating the sprayer.

Step 2. Repeat Step 1.

Step 3.Remove nozzle tips and screens and clean them using a soft brush and kerosene or detergent water.

Step 4. Fill the tank full and add 1 pound of detergent for every 50 gallons of water. Circulate through the bypass pressure regulator and jet agitator for 30 minutes. Flush solution through the nozzles.

Sprayers that have contained 2,4-D or organophosphate insecticides should be cleaned by the following procedure prior to Step 5:

- replace the screens and nozzle tips,
- fill tank half full of water, add 1 pint of ammonia for every 25 gallons of water,
- circulate solution for about 5 minutes, then discharge a small amount of solution through nozzles,
- keep remaining solution in sprayer at least 4 hours, preferably over night, and
- flush remaining solution through the nozzles.

Step 5. Fill the tank half full of clean water, hose down the outside and inside, then flush through the nozzles.

Step 6. Remove tips, discs, strainers, and screens and store in light oil. Store sprayer in a clean, dry structure. If the pump cannot be drained completely, store where it cannot freeze. Oil films should be applied to some types of tanks and possibly the pumps to prevent rusting.

Other preventative measures include:

1) Overhaul pumps yearly during the winter.

2) Protect steel tanks with a light coat of oil or kerosene.

3) Oil or paint coats inside the tank should be those approved for such use.

4) Avoid leaving pesticides in the tank for extended periods of time.

5) Hoses used for chemicals can never be decontaminated; don't use them for drinking water.

6) Caustic soda (lye) is corrosive to aluminum parts so should not be used as a rinse in aluminum tanks.

7) Don't start a pump against pressure; use the proper relief valves.

8) Always consult the manufacturer's recommendations.

CHAPTER IV

GROUND EQUIPMENT CALIBRATION

Application at the proper rate prevents contamination of the environment and crop damage, and insures efficient pest control. Correct application rates depend upon properly calibrated and functioning sprayers and correctly diluted pesticides. For proper dilution ratios and application rates, always refer to the pesticide label.

A. Variables Affecting Application Rates

Sprayer speed, pressure, nozzle openings and spacing, and the viscosity of the spray material affect application rate.

1. Speed

The ground speed of the sprayer should be determined and held constant when calibrating output. Best results occur at three to five miles per hour. Field speed should be identical to speed during calibration.

How to Determine Speed In Miles Per Hour:

Step 1. Set 2 markers in the field 88 feet apart (88 feet is 1/60 of a mile).

Step 2. Select gear and throttle settings on your equipment.

Step 3. From a running start, check the time in seconds required to drive the 88 feet.

Step 4. Divide 60 by the time in seconds required to drive the 88 feet. This will be your field speed in M.P.H. Example: If it takes 15 seconds to drive 88 feet, then the field speed is 60 - 15 = 4 miles per hour.

Table 1 will help you determine ground speed quickly for measured courses of 100, 200 or 300 feet. Determine the time in seconds required to drive the measured course then refer to columns on the left to find miles per hour or feet per minute.

2. Pressures

The flow rate of pesticide relates directly to pressure. Raising the pressure increases the number of gallons applied per acre. Pressure is regulated on most sprayers by a pressure regulator or relief-bypass valve.

Table 1. GROUND SPEED CONVERSIONS

Miles per Hour	Feet per Minute	Time Required in Seconds To Travel 100'	200'	300'
1	88	68	137	205
1.5	132	45	91	136
2	176	34	68	102
2.5	220	27	54	81
3	264	23	46	68
3.5	308	20	40	60
4	352	17	34	51
4.5	396	15	30	45
5	440	13.6	27	41
6	528	11.3	23	34
7	618	9.7	20	29
8	704	8.5	17	26

3. Nozzle Openings

The nozzle opening determines rate of application when pressure is constant. The larger the opening, the greater the amount of spray material applied.

4. Nozzle Spacing

Most sprayers have fixed nozzle spacing. If nozzles are adjustable, moving them closer together will increase the amount of chemical applied per acre.

5. Nozzle Wear

Nozzle wear results in larger nozzle orifices and higher application rates. Sprayers cannot be accurately calibrated if nozzles are worn.

6. Viscosity

Sprayers are usually calibrated with water. If the viscosity of the spray material is considerably different than water, calibrate with the liquid that will be used in spraying. Generally, wettable powder solutions have a higher viscosity than water; oil base solutions have a lower viscosity.

B. Calibration

The following section gives some methods to use in calibrating your sprayer. Prior to calibrating, follow pre-spraying maintenance guidelines in Chapter IV and replace any worn nozzles. Immediately prior to calibration, make sure the pump and lines are full to the shut-off valve.

Sprayer calibration essentially involves determining at what rate your sprayer operates at a given speed and pressure. This figure is used to calculate the acreage that can be sprayed with one tank. The proper amount of pesticide can then be added to each tank to achieve the recommended application rate.

1. Broadcast Spraying - The following three methods apply to broadcast sprayers, i.e. booms, blowers, and foggers:

a. Calibration Jar Method - Precalibrated jars can be obtained commercially. Follow instructions that come with the jar. Lay out a short, measured course (to determine acreage covered), attach the jar under one of the nozzles, and drive the course at a certain speed and pressure. The application rate in gallons per acre can be read directly from the jar. Be accurate in your speed and pressure measurements and in your jar readings.

Applicators may also calibrate their sprayer utilizing a regular quart jar and Table 2. Remember that a quart jar must be filled and then the distance measured.

b. Sprayer Volume Method

Step 1. Fill the tank to a known level with the calibration fluid. Select an area for a tank run which is similar to the area to be treated. Accurately measure off 1/8 mile (40 rods or 660 feet). Spray the test run at the speed and spray pressure to be used when spraying.

Step 2. Return to level ground and refill the tank to the starting level, measuring the amount of water (or spray solution) used.

Step 3. Calculate the sprayer rate (GPA) by the following formula:

$$\text{Gallons Per Acre} = \frac{\text{gallons water added} \times 66}{\text{swath width (feet)}}$$

Step 4. To determine the number of acres that can be sprayed with one tankful, divide the size of the tank (gallons) by the sprayer rate (GPA).

Step 5. Determine the amount of pesticide to be added to the tank by multiplying the acres one tank will spray by the recommended label rate per acre.

Table 2. Distance Required to Catch One Quart per Nozzle at Various Rates of Application

Nozzle Spacing (Inches)	5 gal per acre	7_ gal per acre	10 gal per acre	12 gal per acre	15 gal per acre	20 gal per acre	25 gal per acre	35 gal per acre
6	4356	2904	2178	1742	1452	1089	871	623
8	3265	2180	1633	1305	1089	816	652	466
10	2610	1744	1305	1045	871	652	522	373
12	2178	1452	1089	871	726	544	435	311
14	1868	1245	934	747	624	624	374	267
16	1633	1089	816	652	544	407	326	233
18	1452	968	726	580	484	363	290	207
20*	1036	871	653	522	435*	327	261	187
21	1245	830	622	498	415	311	249	178
22	1188	792	594	475	396	297	238	170
24	1089	726	545	436	363	373	218	156
30	871	581	436	348	290	218	174	124
36	226	484	363	290	242	182	145	104
42	622	415	311	249	207	156	124	89
48	545	363	272	218	182	136	109	78

CAUTION: Check output of all nozzles, and select an average nozzle for calibration.

NOTE: When nozzle spacing is not uniform or when more than one nozzle is used per row, use the average spacing. If three nozzles are used per row and the row spacing is 42 inches, the nozzle spacing would be 42 - 3, or 14 inches.

*EXAMPLE: Using a boom sprayer with nozzles spaced 20 inches apart on the boom, if a quart of the spray material (or water) is collected from one nozzle while the sprayer is traveling a distance of 435 feet, the rate of application is 15 gallons per acre. The speed is accounted for in the distance.

Step 6. If the recommended rate of chemical is given in pounds per acre, the liquid quantity (GPA) can be determined. Divide the pounds of chemical needed per tankful by the number of pounds in one gallon or the acid equivalent of the chemical.

c. Nozzle Volume Method

Step 1. Select container to be used for collecting nozzle spray discharge. Standard measuring containers, calibrated in cups or ounces, are suitable for determining the amount of material collected. Some companies offer calibrated containers for measuring nozzle discharge. Some farmers use plastic bags for collecting the spray samples.

Step 2. In the field to be sprayed, set 2 stakes 40 rods or 660 feet apart.

Step 3. Fill the tank 1/2 or 3/4 full with clear water.

Step 4. Drive the sprayer unit to a position 20 to 30 feet from the course and attach containers to the nozzles.

Step 5. Drive toward the course at the proper speed and turn the sprayer on as the first stake is passed. Proceed toward the second stake maintaining uniform speed and pressure throughout the course.

Step 6. When the boom or nozzles reach the second stake, close the cut-off valve or turn the sprayer "off".

Step 7. Accurately measure the water collected from one nozzle or the average of several nozzles. Multiply by the number of nozzles on the boom for total discharge.

Step 8. Calculate the sprayer rate (GPA) by multiplying the number of gallons used by the factor 66 and divide by the width of the spray swath (feet).

Step 9. Determine the number of acres which can be sprayed with one tankful of spray. This is found by dividing the tank size (gallons) by the sprayer rate (GPA).

Step 10. Determine the amount of chemical to be added to the tank by multiplying the acres one tank will spray by the recommended label rate per acre.

Step 11. If the recommended rate is given in pounds per acre, the liquid quantity (GPA) can be determined by dividing the pounds of chemical needed per tankful by the number of pounds in one gallon (acid equivalent).

2. Band Spraying

Calibration of a band sprayer, where only a part of the total area is sprayed, can be determined by the following steps:

Step 1. Measure and mark 300 feet and calculate the amount of liquid used to spray this measured course.

Step 2. Determine the sprayer rate (GPA) by this formula:

$$\text{Gal./Acre} = \frac{43{,}560\ \text{ft}^2\text{/acre x Gallons used}}{300\ \text{ft. x Band width (ft.) x No. bands sprayed}}$$

Example: One half gallon of spray material was used to spray 300 feet using 2 nozzles spraying 12 inch bands.

$$\frac{43{,}56\ \text{x}\ 0.50\ \text{gal.}}{300\ \text{ft. x 1 ft. x 2 bands}} = 36.3\ \text{gal./acre}$$

Step 3. Determine the number of acres that can be sprayed with one tank and the amount of pesticide that should be added to the tank. This can be done in the same manner as in the nozzle volume method.

NOTE: Acres sprayed include only that covered by the spray pattern and not the area between.

3. Granular Application

Granular application equipment may be calibrated by collecting granules from one or all delivery tubes. Measure the amount collected in pounds. Use the same procedure as for the nozzle volume method. If granules are applied in bands, use the same procedure as for band spraying.

4. Hand Held Sprayer

Use the following procedure to calibrate and fill a hand sprayer:

Step 1. Fill sprayer with carrier, select pressure and spray pattern, and measure a 20 x 20 foot test area.

Step 2. Determine time in seconds needed to spray the test area.

Step 3. Refill the sprayer and run it for the amount of time determined in Step 2. Catch and measure the spray released.

Step 4. Determine the total area that can be sprayed with one tankful by this formula:

$$\text{Total Area} = \frac{\text{Tank size x Test area (ft.}^2\text{)}}{\text{Gallons to spray test area}}$$

Step 5. Determine the amount of pesticide to add to the sprayer:

$$\text{Pesticide in Tank} = \frac{\text{Total area (Step 4) x Label Rate (Gal./Acre)}}{43{,}560}$$

Step 6. Spray using same pressure and spray pattern as during test.

5. Air Blast Sprayers (Orchards)

Using air blast sprayers, speed of travel is the most important factor that ensures good coverage by the pesticide. Equipment speed must be slow enough to allow the air blast to penetrate the surrounding air and carry the spray to the trees. Sprayer speed should be about 2 mph and never slower than 1/2 mph or greater than 3 mph.

Air should be directed toward the top 1/3 of the trees. Edges of the air blast should just clear the tree top and bottom. Vanes or movable air outlets on the sprayer can be adjusted to direct the air. Consult the manufacturer's manual for more precise adjustment of the air stream.

The following procedure is suggested for calibration using two-side delivery:

Step 1. Test run the sprayer using water to determine the best pressure and ground speed. Watch the trees to determine at what speed the air penetrates the trees and turns the leaves.

Step 2. Fill the tank with water and, at the speed and pressure determined from Step 1, spray a measured course (300 ft.). Measure the amount of water needed to refill the tank and calculate sprayer output using this formula:

$$\text{Output (GPA)} = \frac{\text{Row space (ft.) x 300 ft. x Water used (gal.)}}{\text{43,560 sq.ft. per acre}}$$

Step 3. Determine the number of acres that can be sprayed with one tank:

$$\text{Total acres/tank} = \frac{\text{Tank size (gal.)}}{\text{Sprayer output (GPA)}}$$

Step 4. Consult the label application rate if appropriate and determine the amount of pesticide that should be added to the tank:

Pesticide = Total acre/tank x Label Application Rate (GPA)

> NOTE: This method is correct only if all rows in the orchard are to be sprayed. If spraying is planned for alternate rows, then an adjustment must be made to the formula in Step 2.

If the row space changes among orchards, then the figures in Steps 2 through 4 must be recalculated (it is not necessary to repeat the measured course).

Rates for various chemicals, such as Diazinon in cherries, state "spray to cover". This essentially means spray until all leaves are wet or when pesticide begins to drip. Any unnecessary pesticide drip should be avoided. Where labels state "spray to cover", it is essential that Step 1 be done carefully. Mix the pesticide and carrier according to the label dilution rate. Steps 2 through 4 are supplemental in these instances only if you wish to know the spray rate per acre.

6. Ornamental Sprayers

Most label rates for ornamental trees and shrubs state "spray to cover" or "drench". For this reason, it is not necessary to know sprayer output unless the operator wishes to know the volume of pesticide applied to a tree. It is essential, however, to determine the correct pressure that penetrates the foliage and to apply pesticide only to the point of runoff. Pesticide that drips to the ground is wasted and may be environmentally harmful.

It is recommended that applicators and their operators experiment with their equipment filled with plain water utilizing various pressures and disc sizes (4,6,8,10, etc.). By working against a wall or large tree, the proper pressures, discs and spray patterns can be determined.

7. Sample Calculations

The following formulas and examples may be useful study aids or may be helpful when you calibrate your sprayer:

a. <u>To determine acres sprayed</u>

$$\text{Acres sprayed} = \frac{\text{Swath width x distance travelled}}{43{,}560\ \text{ft.}^2\ \text{per acre}}$$

For example, what acreage was sprayed by a boom sprayer with a spray swath of 25 ft. that made 10 passes (no swath overlap) in a field 500 ft. long?

$$\frac{25\ \text{ft. x (500 ft. x 10)}}{43{,}560\ \text{ft.}^2\text{/acre}} = 2.9\ \text{acres}$$

b. <u>To determine rate (GPA)</u> when acreage sprayed and spray volume is known:

$$\text{Rate} = \frac{\text{spray volume (gal.)}}{\text{acres sprayed}}$$

For example, if 2.9 acres were sprayed and 36 gallons of tank mixture was used, what was the rate per acre?

$$\frac{36\ \text{gal.}}{2.9\ \text{ac.}} = 12.4\ \text{gal./acre}$$

c. <u>To determine the amount of pesticide applied per acre</u> when tank mixing rate is known:

Pesticide/ac. = Spray rate (GPA) x label mixing rate, for example, spray rate was 12.4 gal./acre and the pesticide was tank mixed 1 quart per 100 gallons carrier. How much pesticide was applied per acre?

$$12.4\ \text{gal/acre x}\ \frac{1\ \text{qt.}}{100\ \text{gal.}} = .124\ \text{qts. or 1/2 cup}$$

d. <u>To determine how much pesticide should be added</u> to your tank when the sprayer rate is known.

$$\text{Pesticide} = \frac{\text{Tank size (gal.) x label rate (GPA)}}{\text{sprayer rate}}$$

For example, you have test calibrated your sprayer and it applies 12 gallons of water per acre. The tank holds 200 gallons and the pesticide label rate suggests 1 qt./acre. How many qts. of pesticide should you add to your tank to achieve this rate?

$$\frac{200\ \text{gal. x 0.25 gal./ac.}}{12\ \text{gal./ac.}} = 4.17\ \text{gal.} = 16.7\ \text{qts.}$$

e. You have test calibrated your sprayer and found it to apply 7 gallons water per acre. You plan to apply Benlate to beans, and the label rate is 10-20 gal. carrier per acre. What is your next step?

Recalibrate your sprayer to increase the rate (increase pressure, check nozzles for improper size, decrease tractor speed, etc.)

f. To determine correct speed if your test run speed results in sprayer rate that is too low.

$$\text{New speed} = \frac{\text{Present speed (mph) x sprayer rate (GPA)}}{\text{desired rate (GPA)}}$$

Using example, you decide to apply 15 gal. carrier per acre. At 7 mph the sprayer rate was 7 GPA. What is the correct speed?

$$\frac{\text{7 mph x 7 GPA}}{\text{15 GPA}} = \text{3.3 mph}$$

CHAPTER V

AERIAL EQUIPMENT AND CALIBRATION

The subject of aerial spray equipment and accessories is a complex subject suitable for engineers and experienced pilots; however, many aspects of aerial application are similar to ground application. For example, sprayers are basically constructed of the same components. Calibration is accomplished in much the same way except that speeds are much greater and rates much lower. The following chapter contains a general discussion of aerial equipment and accessories and calibration of aerial sprayers. For a more comprehensive discussion of aerial spraying applicators read "The Use of Aircraft in Agriculture" by Akesson and Yates.

A. Types of Aircraft

There are several classes of aircraft that may be utilized for the application of pesticides. These classes include:

1. High wing monoplanes are not primarily designed for applying pesticides, but do provide good visibility, handling, and low maintenance cost.

2. Low wing monoplanes are steadily increasing in use today. Generally, these planes provide increased safety by providing better visibility, stability, and protection to the pilot.

3. Biplanes are the predominant single engine aircraft used for aerial application in some sections of the country.

4. Multi-engine aircraft are utilized extensively in forest and rangeland application.

5. Helicopters have some advantages over fixed wing aircraft, i.e. operate at slower speed; increased safety; improved accuracy of swath, coverage, and placement of the chemical; and they may be operated without airport facilities.

B. Drift

Perhaps the most serious problem associated with aerial application of pesticides is drift of pesticides to non-target areas. Several features of aerial application accentuate this problem:

1. The requirement of low application rates means that spray droplets must be small so that coverage (droplets per acre) will be adequate. Smaller droplets have a greater tendency to drift; droplets 30 microns and smaller remain suspended in air. Spray droplets should be about 100

microns to minimize drift. Table 3 gives an indication of the effect of droplet size on drift.

Table 3. SPRAY DROPLET SIZE AND ITS EFFECT ON SPRAY DRIFT

Drop Diameter Microns 1/	Particle Type	Weather Elements	Distance Moved by 3 MPH wind in 10' Fall
400	Coarse aircraft spray	Light rain	8.5'
150	Medium aircraft spray	Mist	22'
100	Fine aircraft spray		48'
50	Air carrier spray		178'
20	Fine sprays & dusts	Fog	1,109'
10	Usual dusts & aerosols		4,435'
2	Aerosols		21 miles

1/ A micron is about 1/25,000 inch

-- From Akesson & Yates, Ann. Rev. Entom. Vol. 9, 1964

2. Pesticides are generally released at greater heights than from conventional sprayers. This is done to achieve good coverage but also results in pesticide drift caused by wind, convection currents, and aircraft turbulence.

Aerial applications should be conducted when the air is still or nearly so. By spraying early in the morning, convection currents which form at temperatures 85_F. and above can be avoided.

The flight path directly affects the amount of drift. If the aircraft is climbing, there will be more down push and less spray pulled into vortices. If the aircraft is descending, the wing or rotor tip vortices will pull more spray aloft; various portions of the spray pattern will be disturbed as well. Level or slightly ascending flight is usually best to alleviate both effects.

Tests show that there is an increase in drift with more swaths. Barriers near the target area (trees) may help reduce drift and confine it to the target area. For a look at how different factors affect drift, see Table 4.

The following factors can help to reduce pesticide drift:

a. Increase droplet size by the use of invert emulsions (water in oil mixtures), viscosity additives, or foam producing additives.

b. Increase droplet size by using nozzles with larger orifices or by using a jet nozzle.

Table 4. The Effect of Various Factors on Pesticide Drift

Less	Drift	More
Lower	A. Aircraft altitude	Higher
Lower	B. Wind speed	Higher
Larger	C. Droplet size	Smaller
Lower	1. Pressure	Higher
Jet	2. Nozzle type	
Greater	3. Nozzle capacity	Smaller
Larger	4. Orifice size	Smaller
Round	5. Orifice shape	Sharp Angles
Lower	6. Air shear on spray	Higher
Higher	7. Surface tension	Lower
Higher	8. Spray density	Lower
Higher	9. Viscosity	Lower
Down	D. Vertical air motion	Up
Reduced	E. Air stability	Greater
	F. Aircraft turbulence	
Slower	1. Speed	Faster
Climbing	2. Flight direction	Falling
Narrower	G. Swath width	Wider
Less	H. Number of contiguous swaths	More

L.E. Warren, From: Weed Control, Training Session

c. Limit boom length to no more than 3/4 of the wing span.

d. Control droplet size by using the correct pressure.

e. Use atomizers (spinners) at the proper rpm.

f. Fly at the proper altitude.

g. Apply pesticides early in the day before convection currents form.

h. Spray only during calm weather.

i. Choose pesticide formulations that are not volatile.

C. Viscosity Modifiers

Viscosity modifiers are agents which simply increase the viscosity of water or oil carrier. They will create a particulate foam, thixotropic nature (gel to liquid upon shaking), or produce a two-phase mix of oil and water called invert emulsion. These additives increase droplet size and hence, decrease drift.

A particulating agent is a water swellable polymer that absorbs water but does not dissolve. Particulating agents are probably the most effective drift control agents for water soluble herbicides.

Thixotropic wax products act differently than plain thickening agents. When they are added to water, thickening occurs, but when dispersed under pressure or shear, the material thins and thickens again as the spray leaves the nozzles.

An invert emulsion is formed when an oil phase in the water-oil mixture becomes continuous and the water is dispersed in cells, Invert emulsions reduce evaporation because the oil film surrounds the water. Various inverts can reduce drift by as much as 60-99 percent in comparison with normal water sprays.

Invert emulsions can be mixed in the tank before spraying or in the line or pump as they are being sprayed (bi-fluid system). The viscosity of invert emulsions is increased by using more inverting agent, decreasing the oil, and increasing agitation. Oil to water phase ratios may range from 1 part oil to 2 parts water to as high as 1:15.

Individuals interested in viscosity modifers should consult with technical representatives of chemical companies, Extension Service Personnel, or the Montana Department of Agriculture.

D. Equipment for Dispersing Pesticides

Application equipment can be constructed for dispersing dry or liquid pesticides. Since applicators can be asked to apply either type, equipment such as hoppers are often constructed so that liquid or dust formulations can be applied. Following is a discussion of equipment for aerial application of liquid and/or dry pesticides in fixed wing or rotary wing aircraft.

1. Dry Material Application Systems

In a fixed wing aircraft, chemicals are dispensed primarily by ram-air spreaders and spinners. In a ram-air spreader, dry materials are metered from the hopper into the propeller slip stream. Ram-air systems do not have the capacity to spread materials in a wide swath. This led to the development of spinners. These devices consist of spinning vanes mounted under the hopper that throw material outward in a uniform pattern. Some equipment, to further increase spreading power, utilizes a blower to force material into the spreader. The use of spreaders and blowers can nearly double the swath width.

In helicopters, two types of dispensers are used.

1) A blower driven by the engine forces material from two side tanks and out short booms. The material may be spread using spinners instead of the boom.

2) A single hopper can be suspended on a cable and material dispensed using spinners. This method eliminates the problem of aircraft trim caused by uneven emptying of side tanks.

Agitators, to insure even dissemination of material from the tanks, may or may not be present. They are essential for materials smaller than 60 mesh. Their use will help insure even application by providing an even flow of material.

The hopper or tank for dry materials should have many of the characteristics of a tank for holding liquids. Corners should be rounded and the sides should be steep to insure unloading of the chemical. Usually a slope of 50_ to 55_ is adequate. Tanks can often be used for dry or liquid materials by replacing a bolt-on plate on the tank bottom with a hopper.

2. Liquid Material Application Systems

There are two types of spray systems for fixed and rotary wing aircraft:

1) pressure type - the spray is applied under specific pressures.

2) gravity feed - the flow of spray solution from the tank to dispersing unit relies upon gravity.

Aircraft spray dispersal equipment consists of a tank(s), pump(s), pressure regulater, line filter, flow control valve, boom and nozzles. Swath widths of 40 to 60 feet, in the application range of 1 to 10 gallons per acre are normal when material is released 5 to 8 feet above the ground.

a. Tanks for fixed wing aircraft are usually mounted internally, often ahead of the pilot and aft of the engine, however, quick release belly tanks can be mounted to the aircraft bottom. This permits rapid jettison of the tank should the need arise. Also, aircraft not primarily used for spraying can be modified to do so.

In rotary wing aircraft, tanks are mounted externally on the side or underneath.

All tanks should have emergency dump valves located on the tank bottom. Internal baffles are required to prevent rapid shifts in fluid.

b. Two types of agitation systems are utilized to maintain suspensions and mixtures of chemical. Mechanical systems rely on paddles to maintain agitation. Hydraulic systems utilize a return flow from a large capacity pump. A rule of thumb is that the flow rate should be 10 GPM for every 100 gallons of tank capacity.

c. The most common pump is that driven by a small propeller in the slip stream of the aircraft engine propeller. The efficiency of this type of pump is low and many newer aircraft are equipped with hydraulic piston pumps or electric pumps.

Helicopter pumps are usually driven by a PTO. Centrifugal pumps are the most common type where application rates are 1-10 gal./acre. Where higher pressures are needed, as for aerosols, or where pump discharge is greatly reduced, other pump types such as gear or roller are used.

d. Pressure regulators or by-pass relief valves are utilized to maintain a constant spray pressure. Pressure regulators are located between the pump and boom and include a quick closing shut-off valve. These valves allow the spray system to be opened and closed instantly.

e. The main control valve is usually 3-way. In the "spray off" position, the valve directs flow from the pump back into the tank through a venturi section. This action maintains a slight vacuum in the boom to prevent pesticide dribble, and provides recirculation agitation in the tank. A third valve position allows the tank to be filled or emptied through the boom.

f. Screens or filters are generally located in three places in liquid systems. A coarse screen at the tank bottom keeps debris from entering the pump. The most important screen is one located between the pump and the booms. It is usually 25 to 100 mesh (10-40 openings per centimeter) and can be removed easily for cleaning. Mesh size depends upon nozzle orifice size so that particles that might plug the nozzles can be removed. A third screen is usually placed just before each nozzle orifice.

g. Pipes and fittings usually have the following characteristics that help prevent pressure losses:

1) For application rates over 2 gallons per acre, all main piping and fittings are 1-1/2 inches inside diameter.

2) For application rates of 1/2 to 2 gallons per acre, all main piping and fittings are at least 1 inch inside diameter.

3) For ULV applications, hoses to individual nozzles should be 1/8 inch inside diameter. Main line hoses and fittings should be at least 3/8 inch inside diameter.

The number of bends and joints should be minimized. All hose connections should be double clamped and lines under pressure should not run through the cockpit.

h. Booms for fixed and rotary wing aircraft, although mounted differently, are basically the same in construction. Boom pipes are round or aerodynamic in cross section. In fixed wing aircraft, they are mounted on the trailing edge of the wing and usually are 3/4 the wing span length.

i. Nozzles used in aerial spraying are basically of 4 types:

1) The jet or solid stream nozzle produces a jet of coarse droplets useful for coarse sprays such as 2,4-D.

2) Hollow cone nozzles, identified because of their spray pattern, produce small droplets.

3) The flat fan nozzle produces a fan shaped pattern and is useful in reduced volume applications.

4) An atomization nozzle produces a true aerosol spray in a cone shaped pattern.

j. Atomizers, in addition to the atomizing nozzle, include a variety of spinning screen cages, discs, and wire brushes. They are usually driven by fans or electric motors. Atomizers produce droplets of more uniform size and are useful in low volume spraying such as grasshopper or mosquito control.

Droplet size is influenced by a complex interaction among pressure, spinner speed, air shear, and discharge angle. For example, as pressure (flow rate) increases, droplet size increases. As spinner velocity increases, droplet size decreases. The angle of discharge from the nozzle in relation to the airstream influenced droplet size. Smaller sized droplets will be produced if nozzle discharge is directed at 90_ relative to the slip stream.

E. Safety and Maintenance

The safety section in the General Pesticide Training Manual also applies to aerial applicators. The following additional rules also apply:

1. Because pilots must fly through previous swaths, a clean air supply is necessary. If a filtered air helmet is not available, use an approved respirator.

2. No hoses, valves, or any portion of the system carrying pesticides should pass through the cockpit.

3. Components of the spray system inside the fuselage should be accessible for cleaning, maintenance, and repairs.

4. The critical demands of aerial pesticide application require regular maintenance. The seasonal nature of pesticide application lends itself to inspections and repairs during idle periods.

F. ULV Application

The present trend in pesticide application is to apply highly concentrated material at low rates. Ultra low volume (ULV) rates for mosquito control are as low as 0.1 gallon per acre.

The application of ULV formulations requires the use of special equipment and application procedures. Conventional aircraft spray systems can be modified to accomodate ULV formulations. A small ULV system can be installed separate from the dilute system and can be removed upon completion of ULV operations.

The following points should be observed when applying ULV applications: ULV systems must deliver fine droplets to be effective. This can be accomplished by utilizing spinning or flat fan nozzles discharging 0.1 GPM or less at 40 to 55 psi. Gaps in the distribution pattern can be avoided by using not less than four flat fan nozzles. For helicopter operations, a single spinning nozzle may provide adequate output at very low rates such as required for mosquito control.

Because of the fine droplets produced by ULV systems, the location of the nozzles is important. Extreme outboard nozzles must be located away from the wing tips on fixed wing aircraft to avoid spray entrapment in the wing tip vortices. Central nozzles can be shifted to the right to compensate for propeller wash.

ULV application should be made at the altitude that will achieve the optimum spray width strip. As wind velocity increases, the aircraft altitude should decrease.

Carriers used in ULV formulations may cause premature wearing of certain equipment parts. For instance, the carrier for Malathion will corrode rubber and neoprene. To minimize chemical damage to spray equipment; seals, hoses, and nozzle diaphragms should be checked regularly and replaced if corrosion has begun. Nozzle screens should also be checked regularly since the smaller tips become clogged more easily.

G. Calibration

The same variables that apply to ground equipment also apply to aerial calibration, i.e. speed, pressure, nozzle spacing, and swath width. Aerial applicators should be familiar with the sections in this manual dealing with ground equipment and accessories, ground equipment calibration and maintenance. Precise calibration is essential in order to apply the correct rates and to guard against crop injury caused by overdoses of pesticide.

1. Swath width must be known before calibration can proceed. Because aircraft wheels nearly touch the crop during application, swath width is about the same as boom width or is related to the ram-air or spinner type spreader.

To make a precise measure of swath width, flights can be made over collecting surfaces arranged in a line perpendicular to the line of flight. Dyed sprays can be deposited on cards or plastic plates and the amount of pesticide or liquid deposited can be measured. Deep baskets or buckets or oiled surfaces can be used to collect granules. From the information gathered, swath width and deposit pattern can be determined. Be sure to determine effective swath width, or that swath width in which pesticide was deposited in sufficient quantity to give control.

2. When air speed and swath width are known, the rate at which pesticides should be dispensed can be found using this formula:

$$\text{Rate (GPM)} = \frac{\text{Label rate (GPA)} \times \text{Swath width} \times \text{Air speed}}{495}$$

For example, the 100 mph aircraft has a 40 foot effective swath width. Label rate instructions call for 10 GPA. At what rate should the aircraft be calibrated?

$$\frac{10 \text{ gal./acre} \times 40 \text{ ft.} \times 100 \text{ mph}}{495} = 80.8 \text{ gal./min}$$

For dry materials, the discharge rate thus obtained can be established by actual flight tests for ram-air spreaders. Spinners can be calibrated by operating the equipment on the ground.

For liquid pesticides, the discharge rate can be obtained by selecting nozzle type and size. The number of nozzles on the boom can be adjusted to give the proper discharge rate to determine the correct number of nozzles, use the following formula:

$$\text{No. Nozzles} = \frac{\text{Discharge rate (GPM)}}{\text{Flow rate per nozzle (GPM)}}$$

For example, flow rate should be 80.8 GPM and the flow rate for the nozzles selected is 6.7 GPM. How many nozzles will give the proper flow rate?

$$\frac{80.8 \text{ GPM}}{6.7 \text{ GPM}} = 12 \text{ nozzles}$$

Small alterations in discharge rate can be made by adjusting pressure.

3. To determine the number of acres that can be treated with one tank or hopper, use this formula:

$$\text{Total acres} = \frac{\text{Tank size (gal.)}}{\text{Rate per acre (GPA)}}$$

4. As a final check on calibration, it is desirable to make an actual flight check. After the tank is filled with a known quantity or to a marked level, a flight is given time or distance is made. The amount of material applied can then be determined by filling the tank to its original level. The quantity applied per acre can be determined and will indicate the accuracy of calibration. Table 5 provides a quick reference for determining acreage sprayed for a given swath width and field length.

Table 5. Acres covered for given field lengths and swath widths.

Field Length	Swath Width (ft) 20	25	30	35	40	45	50	55	65	75	85	95	100
ft. (mi)	..........................acres*..												
1 320 (1/4)	0.6	0.75	0.9	1.1	1.2	1.4	1.5	1.7	2.0	2.3	2.5	2.9	3.0
2 640 (1/2)	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.9	4.5	5.1	5.7	6.1
3 960 (3/4)	1.8	2.3	2.7	3.2	3.6	4.1	4.6	5.1	5.9	6.8	7.7	8.7	9.1
4 280 (1)	2.4	3.05	3.6	4.2	4.8	5.5	6.1	6.7	7.8	9.1	10.2	11.6	12.1
2	4.9	6.05	7.2	8.4	9.8	10.9	12.1	13.3	15.6	18.2	20.8	23.0	24.2
3	7.25	9.1	10.8	12.6	14.5	16.4	18.2	20.0	23.4	27.3	30.8	34.6	36.4
4	9.7	12.1	14.4	16.8	19.4	21.8	24.2	26.6	31.2	36.4	41.2	46.0	48.5
5	12.1	15.15	18.0	21.0	24.2	27.3	30.3	33.3	39.3	45.5	51.4	57.6	60.6

*Acres = (Length in ft. x width in ft./43,560)

Appendix

CONVERSION FACTORS FOR UNITS OF MEASUREMENT

Units of Volume - Liquid Measure

3/4 fl. dram	=	1 teaspoon	=	4.9 milliliters (ml.)
3 teaspoons	=	1 tablespoon	=	14.7 ml.
2 tablespoons	=	1 fl. ounce	=	29.57 ml.
8 fl. ounces	=	1 cup	=	236.58 ml.
2 cups	=	1 pint	=	473.17 ml.
2 pints	=	1 quart	=	946.33 ml.
4 quarts	=	1 gallon	=	3.79 liters
1 kiloliter	=	1000 liters	=	264.2 gallons
1 liter	=	1000 milliliters	=	1.06 quarts
1 milliliter	=	1000 microliters	=	0.03 fl. ounces

Units of Length

		1 inch	=	2.54 centimeters
12 inches	=	1 foot	=	3.05 decimeters
3 feet	=	1 yard	=	0.91 meter
10.5 feet	=	1 rod	=	5.03 meters
1760 yards	=	1 mile	=	1.61 kilometers
1 kilometer	=	1000 meters	=	0.62 miles
1 meter	=	10 decimeters	=	39.37 inches
1 decimeter	=	10 centimeters	=	0.33 inches
1 centimeter	=	10 millimeters	=	0.39 inches

Units of Area

		1 square inch	=	6.45 sq. centimeters
144 sq. inches	=	1 square foot	=	929.03 sq. centimeters
9 sq. feet	=	1 square yard	=	0.84 sq. meters
30.25 sq. yards	=	1 square rod	=	25.29 sq. meters
160 sq. rods	=	1 acre	=	4046.4 sq. meters
43560 sq. feet	=	1 acre	=	0.40 hectare
1 hectare	=	10,000 sq. meters	=	2.47 acres
1 sq. meter	=	100 sq. decimeters	=	1.20 sq. yards
1 sq. decimeter	=	100 sq. centimeters	=	0.11 sq. feet
1 sq. centimeter	=	100 sq. millimeters	=	0.15 sq. inches

Units of Mass (metric and Avoirdupois)

		1 grain	=	1000 milligrams
437.5 grains	=	1 ounce	=	28.35 grams
16 ounces	=	1 pound	=	0.45 kilograms (kg).
2000 pounds	=	1 short ton	=	907.2 kg
1.12 short tons	=	1 long ton	=	1016.0 kg
1 kilogram	=	1000 grams	=	2.2 pounds
1 gram	=	1000 milligrams	=	0.35 ounces