EQUIPMENT USED IN PUBLIC HEALTH PEST MANAGEMENT

One of the most important aspects of public health pest management is the ability of a pesticide applicator to properly use and maintain pesticide application equipment and surveillance devices. Hundreds of different kinds of sprayers, aerosol generators, dusters, traps and other devices have been designed, manufactured, and marketed. Selection of appropriate equipment is important since knowing both when and how to apply pesticides requires a high level of competency.

I. PESTICIDE APPLICATION EQUIPMENT

Regardless of how well trained a pesticide applicator may be, high-quality and dependable equipment is essential. In addition, successful pest management involves the regular use, cleaning, calibration, and repair of this equipment. Sprayers and dusters are used to apply liquid or solid pesticides and most applications, whether spray, dust, or aerosol, are conducted in a manner that seeks to produce uniform coverage. Mist and fog applicators disperse the insecticide as fine particles. Liquid formulations are applied using compressed air sprayers, hand pump atomizers, aerosol dispensers, pistol sprayers, hydraulic sprayers, fog generators and aerial sprayers. Solid formulations are applied as dusts, granules, pellets, and baits, using shaker cans, foot pumps, hand bellows, bulb dusters, plunger and rotary dusters, seeders, and ground and aerial power dusters.

This chapter focuses on the basic design and use of each major equipment group, but equipment technology is improving and new developments make possible even safer and more accurate application of pesticides. Applicators need to stay informed of new technology by regular review of trade magazines and equipment brochures, attendance at educational conferences and seminars and other forms of information exchange.

The Relationship between Pesticide Application and Particle Size

Before discussing specific forms of equipment, it is important to understand the relationship between application and particle size. The effectiveness of a pesticide is greatly influenced by the size of the droplets or particles which are applied. For example, for residual applications a spray may be desirable to wet the surface and leave a long-lasting deposit; whereas, with a area spray ,to kill mosquitoes and flies on the wing an aerosol, mist or fog would be used so that the insecticide remains suspended in the air to extend the period of insect exposure to the droplets.

Liquid sprays range from rain-like drops to mists and fogs produced by specialized generators. It may be impractical, if not impossible, to break up a liquid into entirely uniform droplets, although the range of droplet size may be considerably restricted. There are always some finer droplets among the others. The usual practice to characterize droplets is to refer to the mass median diameter (mmd) of the spray, which is the droplet diameter size that divides the volume or mass of the spray into two equal portions. The unit of measurement is the micron, 1/1000 of a millimeter or about 1/25,000 of an inch. The average diameter of a human hair is about 100 microns.

Liquid applications may be categorized as follows:

- **Coarse** sprays contain droplets 400 microns or more in diameter which are produced with coarse disc nozzles or solid-stream gun nozzles.
- **Fine** sprays have droplets ranging from 100 to 400 microns, produced with high pressure through hollow-cone and fan-spray nozzles.
- **Mists** range in droplet size from 50 to 100 microns in diameter. They are produced by high pressure pumps, high-speed mechanical rotors, and atomizers.
- **Aerosols and fogs** are be defined as assemblages of solid particles or liquid droplets suspended in air and ranging in size from 0.1 to 50 microns. These may be produced by spraying the pesticides into a blast of hot air as with the thermal aerosol generator, or by mixing them with a liquefied gas which is then released through small orifices, as with the household "bug bomb." They can also be produced by atomization from specialized nozzles, or by being thrown off the rim of high-speed rotors.
- **Smokes and fumes**, particles in the range of 0.001 to 0.1 microns in diameter, are commonly produced in the output of thermal fog generators. The generators use the exhaust of an internal combustion engine to almost completely vaporize the oil carrier or to partially combust the pesticide formulation.
- **Vapors** consist of airborne insecticide in droplet-sizes less than 0.001 micron.

Insecticidal dusts occur in three sizes:

- **Coarse** - about 175 microns or larger. This size is used to avoid to avoid excessive drift.
- **Medium** - from 45 to 175 microns.
- **Fine** - 44 microns or less. These droplets will pass through a 325-mesh screen.

Pesticide applications used for control of public health pests are labeled as space treatments, spot treatments, crack and crevice treatments, perimeter treatments, and area treatments. **Space treatment** may occasionally require that a building be sealed before releasing an aerosol or mist within a structure. **Spot treatments, crack and crevice treatments, and perimeter treatments** are localized applications to specific areas where the pests hide or rest, e.g., baseboards, closets, under sinks, as compared with treatment of the entire infested area. Usually the label directions advise application of solutions to wet the surface. This type of application may also be conducted outdoors as, for example, residual sprays applied to the resting sites of mosquitoes, flies or other arthropods, such as culverts, the undersides of bridges, and outer walls of structures. Area treatments are conducted outdoors for a variety of situations that require application to habitats or to infestation foci

Remember, the applicator loses control over the pesticide once it leaves the confines of the equipment. The pesticide becomes a part of the environment into which it has been introduced. It may both alter and be altered by that environment. Regardless of how careful and precise the applicator is in the placement of a pesticide, some of it may not reach the target. The amount of pesticide lost depends upon the circumstances of application and the form of the pesticide. When making applications in sensitive areas, be extra careful, monitor weather conditions and make changes in application equipment to minimize off-target movement.

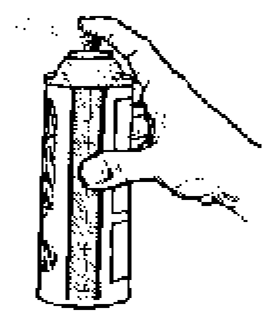
SPRAYERS

Sprayers vary from the hand-pumped flit gun with a tank capacity of as little as one cup to large hydraulic machines powered by gasoline engines with tanks that can hold several hundred gallons of formulation. The common elements include a tank, a device to pressurize the liquid, a delivery line leading to a cutoff valve, and another delivery line leading from the valve to a nozzle. Other items found on sprayers, both simple and complex, are special accessories to enhance the operation. These features are discussed below in connection with specific types of equipment.

Hand Sprayers.

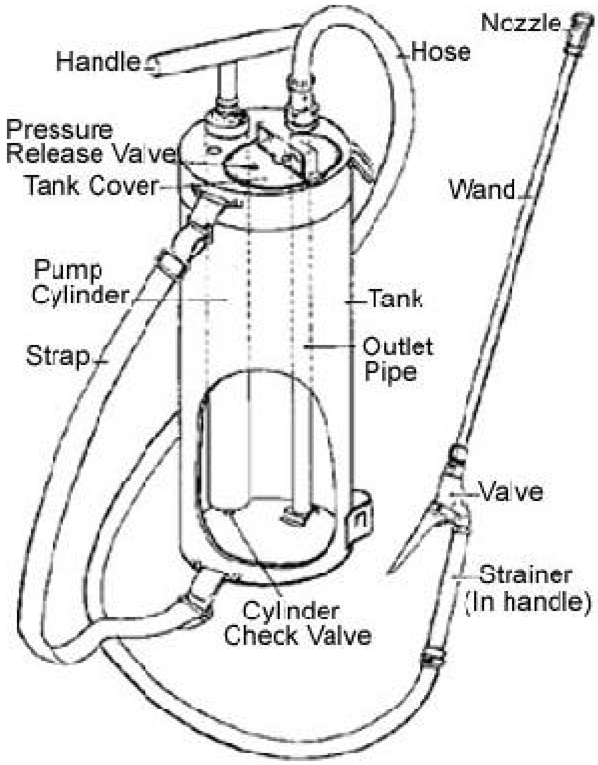
Hand sprayers are one of the most important types of equipment used in controlling insects of public health importance. Several types are described and illustrated in this manual.

The aerosol dispenser is more widely used by the general public than any other type of insecticide applicator. It is available as small, low-pressure, disposable "bug bombs" used by the average householder, or as larger, high-pressure, refillable aerosol dispensers used in some public health programs and by pest control operators.



A small dispenser, designed primarily for indoor use, consists of a disposable container charged with an inert gas and an appropriate insecticide solution. It has a discharge valve and nozzle at the top and a tube extending from the valve to the bottom of the can. The pesticide, in an oil solution, is mixed with the propellent (usually a nontoxic gas in liquid form) and placed in the can at the time it is assembled. When the discharge valve is pressed, the propellent gas forces the insecticide and propellent mixture through the nozzle and it is atomized into a fine mist. These aerosol dispensers can contain a variety of insecticides and are often designed to provide quick knockdown when sprayed directly onto the pests or into the infested space. A synergist such as piperonyl butoxide (PBO) and one or more synthetic insecticides are usually the active ingredients in these containers. One specialized bomb is designed to throw a fine stream for 10 to 20 ft to spray nests of stinging insects, such as wasps and hornets, from a safe distance. Aerosol dispensers should be stored in a cool place and discarded when empty. They should not be incinerated.

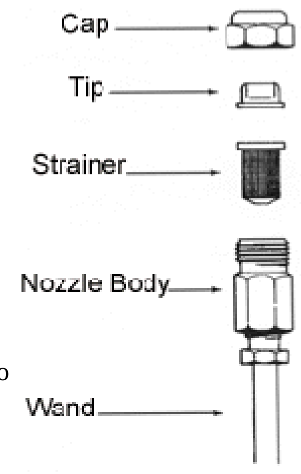
The **pistol sprayer** is very much like the "gun" used for oiling automobile springs. A fine, solid stream of insecticide is produced by pulling the trigger. It is especially valuable when small amounts of pesticide solution or emulsion need to be applied to cracks and crevices or other pest harborages. Pistol sprayers are designed to resist corrosive chemicals and are fitted with a plastic container as a reservoir.



The **compressed air sprayer** is a mainstay of many public health insect control projects. It is commonly used indoors to apply residual sprays for control of fleas, cockroaches and other types of household pests, and outdoors for small area treatment. The **tank**, made of stainless steel, brass, plastic or galvanized steel, forms the body of the sprayer with a capacity usually ranging from 0.5 to 3 gal and serves as the reservoir for the spray mixture. The space above the spray mixture is pressurized by a hand pump in manually operated units. The pump cylinder ordinarily is fitted to the head of the spray tank with rubber gaskets and has a check valve at the bottom that permits air to be pumped into the sprayer, but prevents air or liquid from being forced back into the pump barrel. The air pressure forces the spray mixture through an **outlet pipe** to the **spray hose**.

The **spray gun**, mounted at the end of the spray hose of the compressed air sprayer, consists of a cutoff valve, wand and nozzle. The cutoff valve may be a simple ball valve installed against the nozzle tip to prevent the nozzle from dripping. Some sprayers provide both a constant pressure valve on the tank and a no-drip cutoff valve at the nozzle tip. The valve uses a trigger which allows the insecticide stream to be turned on and off. High quality sprayers have a strainer made of fine wire mesh inserted near the valve. The **wand** is a slender metal tube extending from the spray hose to the nozzle. Straight wands are considered easier to use than those that are angled near the tip. To reach further, and to help prevent splash-back of pesticides onto the applicator, two or more wands may be joined together or a single long wand may be used. Sprayers often are equipped with a carrying strap and handle.

Some compressed air sprayer tanks have a valve to release air pressure at the end of the spraying operation and for charging the tank with compressed air, in place of using a hand pump. Sprayers with no such air release must be turned upside down to release the air through the wand in order to reduce the pressure before opening. Operator injury, contamination and gasket damage are likely consequences of opening the head of a sprayer before discharging the compressed air.



Nozzle systems have 4 major components: nozzle body, cap, strainer (screen), and tip or orifice plate. They may also include a separate spinner plate or whorl chamber. Successful spraying depends on the correct nozzle selection, assembly, and maintenance. Nozzle tips break the liquid into droplets and distribute the spray in a predetermined pattern and are the principal element controlling the rate of application. Nozzle performance depends: on nozzle design or type, operating pressure, size of the opening, discharge angle and distance of nozzle from the target. Nozzles are available in several materials. Tungsten carbide nozzles and ceramic nozzles are very resistant to abrasion and corrosion and are the most expensive. Stainless steel nozzles with good corrosion and abrasion resistance, if they are hardened, are moderately priced. Plastic nozzles resist abrasion better than brass, are moderately expensive and will not corrode, but may swell when exposed to organic solvents. Brass nozzles resist corrosion (except from fertilizers), but not abrasion, and are moderately expensive. Aluminum nozzles are inexpensive and are resistant to some corrosive materials.

The **nozzle** is the smallest but perhaps the most important component of any sprayer for it determines how the insecticide will be sprayed, the rate of spray output and the droplet spectrum at a given pressure. Effective application depends on proper nozzle functioning. If two or more nozzles are placed at the end of a wand, the spray gun is referred to as a spray boom. Some sprayers, e.g., the orchard spray gun, employ a single nozzle that can be adjusted to produce spray patterns varying from a solid stream to a fine mist by reducing the size of the whorl chamber. Many commercial compressed air sprayers have adjustable nozzles. However, non-adjustable nozzles are desirable for public health insect control programs, because they can be depended upon to deliver a definite amount of insecticide per unit of time.

Nozzle tips are designed to deliver specific volume and spray pattern at a set pressure. The following text table illustrates some of the variety of options available and shows, for example, that the coarse-fan orifice delivers more than twice as much as the fine-fan orifice at a fixed pressure:

Pattern	Spray angle	Oz of spray/min @ 20 psi
Coarse fan	50°	14.08
Fine fan	80°	6.40
Broad pin-stream	Straight	8.96
Fine pin-stream	Straight	4.48
Crack & crevice straw	Straight	3.84
Aerosol-tip straw	Straight	7.04

By selecting the proper nozzle the operator can apply the insecticide in the pattern desired. A primary function of the nozzle is to obtain uniform distribution whether the insecticide is deposited on a surface, on water, or dispersed into the air. Four nozzle patterns are commonly used with compressed air applications by public health workers:

- **Solid stream** - applies a fine stream of insecticide to treat cracks and crevices with insecticide to control cockroaches, ants, bed bugs, ticks, etc.
- **Flat spray** - distributes the insecticide in a thin band that issues fan-shaped from the nozzle opening and is used chiefly to place residual sprays on surfaces much as a large paint brush would.
- **Hollow cone** - with large aperture, is employed for surface spraying of suspensions and other materials, e.g., for mosquito larviciding or treating vegetation for control of ticks and mites.
- **Solid cone** - is used for mosquito larviciding and area treatment of vegetation.

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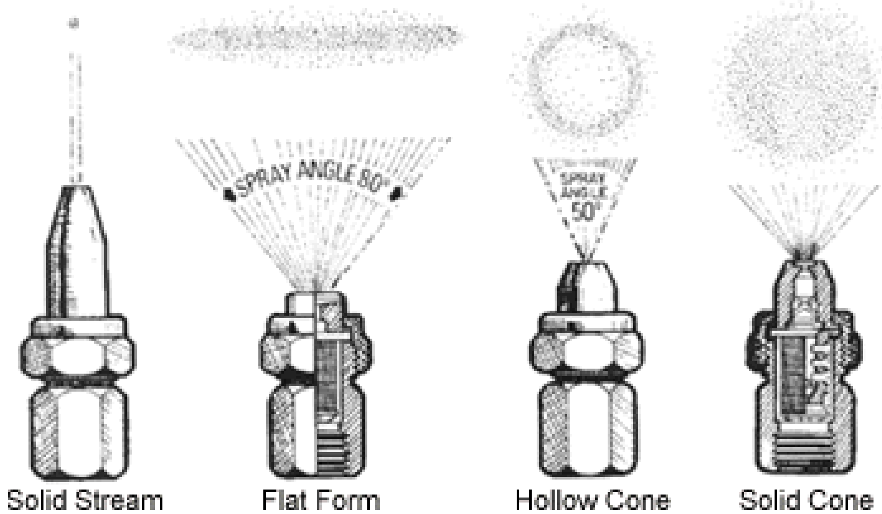


Some special purpose nozzle tips or devices produce special patterns, such as raindrop, flooding, wide angle fan or cone-shaped patterns. For residual spraying on surfaces, best results are obtained using the flat spray nozzle. By moving the wand of the sprayer in a direction perpendicular to the fan of the nozzle, the spray is applied until the surface is wetted to the point of run-off. With this type of nozzle, a uniform application can be applied with little waste of material. For aquatic habitats of mosquito larvae, such as relatively narrow roadside ditches, potholes or other small sites, the hollow cone nozzle tip on a sprayer wand is best.

Some nozzles supplied with compressed air sprayers have a nozzle disc consisting of a simple steel plate with a hole in the center instead of the standard nozzle tip. These discs often have numbers stamped on them ranging from 1 to 10, representing 64ths of an inch. Thus, a number 7 disc would have an aperture of 7/64 inch in diameter, and would produce large droplets suitable for heavy applications, whereas a number 1 disc would produce a very fine spray. Disc nozzles are commonly used for large power sprayers which operate at high pressures, producing a very fine mist. They are also satisfactory for applying insecticide suspensions with the compressed air sprayers.

Several manufacturers have developed nozzle systems in which carefully calibrated nozzles are designated by number (Table 11-1) and predictable delivery rates (Table 11-2).

Table 11-1. Examples of Teejet* Nozzle Systems

Nozzle Tip	Pattern & Angle	GPM **	Use
50015	Flat - 50º	0.15	Residual spraying on very smooth surfaces
8002	Flat - 80º	0.20	Residual spraying on ordinary surfaces
5004	Flat - 50º	0.40	Residual spraying on porous surfaces
0001	Solid - 0º	0.10	Cockroach control ****
TGI	Hollow Cone - 60º	0.20	Mosquito larviciding. Residual spraying of small areas
Adjustable cone jet 5500-x18	Cone or stream	0.97	Mosquito larviciding where both cone and stream are desirable
Multeejet*** #5700 50015	Flat - 50º	0.15	Residual spraying on very smooth surfaces
730039	Flat - 73º	0.039	Mosquito larviciding
000021	Solid - 0º	0.021	Cockroach control in residences or hotels ****
0001	Solid - 0º	0.10	Cockroach control ****

* Spraying Systems, Inc., Wheaton, Illinois, 60187
** Gallons per minute at 40 psi
*** This nozzle has four different apertures
**** If within a structure, consider using baits and IGRs instead of sprays.

It is important to use the proper nozzle. Teejet nozzles are rated according to the angle at which the spray leaves the nozzle and to the output in tenths of a gallon per minute at a pressure of 40 psi. Thus, the 8002 nozzle used in residual spraying of emulsions on ordinary surfaces produces a flat fan spray at an 80º angle with a rate of 0.2 gal/min at a pressure of 40 psi. Similarly, the 5004 nozzle used in residual spraying of suspensions on porous surfaces produces a flat fan spray with a 50º angle with a rate of 0.4 gal/min at a pressure of 40 psi; and the 8001 nozzle used to apply emulsions or solutions to cracks and crevices for cockroach control produces a solid stream at 0.1 gal/min with a pressure of 40 psi. Many pest control operators and public health workers in buildings need to change the spray pattern from time to time as they work through a building. Therefore, they use a Multeejet nozzle with 4 openings, two (50015 and 730039) to produce fan type sprays, and two (000021 and 0001) to produce solid stream sprays. The spray pattern depends primarily on the type of nozzle used and secondarily on the air pressure in the sprayer tank.

Table 11-2. Application Rates for Teejet Nozzles at Various Insecticide Concentrations*

Concentration	**Insecticide deposit in mg/ft^2**			
(%)	8001	50015	8002	5004
0.3	6	9	12	24
0.5	10	15	20	40
0.625	12.5	18.75	25	50
0.75	15	22.5	30	60
1.00	20	30	40	80
1.25	25	37.5	50	100
1.50	30	45	60	120
2.00	40	60	80	160
2.50	50	75	100	200
3.00	60	90	120	240
3.50	70	105	140	280
4.00	80	120	160	320
5.00	100	150	200	400

* Surfaces treated at rate of 190 ft^2/min with pressure of 40 psi.

When being trained to treat surfaces with the 8002 nozzle, the applicator should be taught to spray at 18 inches from the surface at a rate to cover 190 ft2/min. Because it is difficult to apply sprays at a consistent rate, personnel are taught to use a single pace and vary the concentration or nozzle when a different level of deposit is required. This is much easier to learn than to vary the pace and use a single concentration. For example, using a 2.5 percent malathion emulsion at the standard delivery pace (190 ft2/min), the resulting dosage will be 100 mg of active ingredient per ft^2 (a.i./ft^2). A 5004 nozzle could be used to apply a 1.25 percent wettable malathion at the same rate

(100 mg a.i./ft^2) using the same pace (190 ft^2/min) because this nozzle delivers twice the volume of the 8002 nozzle. In this case the insecticide concentration is reduced by one-half to compensate for the twofold increase in delivery rate. In each case, if the nozzle or nozzle aperture were changed, other conditions remaining the same, the application rate would change and the desired 100 mg a.i./ft^2 application would not be achieved. In cases where more or less insecticide per ft^2 is desired without changing nozzles, it is necessary to increase or decrease the concentration of the spray in order that the operator may work at the usual uniform speed of application. Thus, to apply 200 mg a.i./ft^2 you could use the 5004 nozzle with a 2.5 percent solution.

The pressure mentioned above, 40 psi, is not always best because the correct pressure for the sprayer varies according to the type of insecticide application. For crack and crevice treatments, pressures of less than 10 psi are most effective. For general and spot treatments, which are most often performed using either the fine-fan or coarse-fan nozzles, the effective operating pressure is between 20 and 25 psi. Fine-fan applications at this pressure would be used for flea treatments on carpeting, for example; or coarse-fan applications would be used along outside foundation walls.

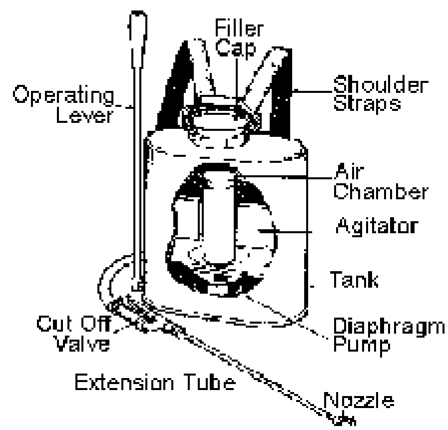
Low pressure is usually recommended for spray applications inside structures. Constant use of high pressure with compressed-air sprayers create the possibility for misapplication. The high pressure causes part of the sprayed liquid to break into smaller droplets as soon as it exits the nozzle, which wastes material and might result in drift onto non-target surfaces. High pressure may cause splash-back on surfaces or quickly trap air in crevices and small spaces and keep the pesticide from entering. Establishing and maintaining correct pressure in the sprayer is important for obtaining good insect control and for safety. Keep in mind the following:

- Sprayer pressure affects the amount of insecticide applied and the type of pesticide coverage. Too much or too little pressure often causes spotty and uneven coverage and poor pest control.
- High pressure is seldom necessary. Excessive pressure may increase the hazards both to the applicator and to the public because of the possibility of hoses bursting under pressure. Insecticide particles delivered at high pressures tend to bounce off the target surface, which is wasteful and may expose untargeted objects, animals and humans.
- Continued excessive pressure causes premature wear and possible damage to the sprayer components.
- Some insecticide labels dictate the pressure appropriate for applications against specific pests.

Proper routines for using the sprayer are critical for effective insect control and safety, and for keeping the sprayer in good working order. The following points provide key basics for effective and safe use:

- Correct filling is important to achieve a good mixture of water and insecticide. When filling the sprayer, do not place the pump unit of the sprayer where it can collect dust, dirt, or contaminants that may clog it or undesirable pesticide residues. Use clean water. First fill the tank about one-quarter full with cool water, add the concentrate and then adding the remaining water. Do not use warm water to mix sprays as it may accelerate the breakdown of the pesticide, create droplets that easily float, and increase the pesticide's odor. Fill the tank to only 3/4 full of its total capacity and use the remaining 25 percent of space to build up air pressure. If 40 psi is desired, initially the air should be compressed to about 55 psi, after which spraying may continue until pressure drops to approximately 25 psi. Then pressure is again pumped up to 55 psi. In this way, an average pressure of 40 psi is maintained to produce the delivery rate and spray characteristics for which many nozzles are designed. Spray applicators soon learn to judge the correct pressure for spraying by observing the spray pattern. The applicator may wish to attach a pressure gauge and a lever to the spray tank to maintain a more consistent tank pressure.

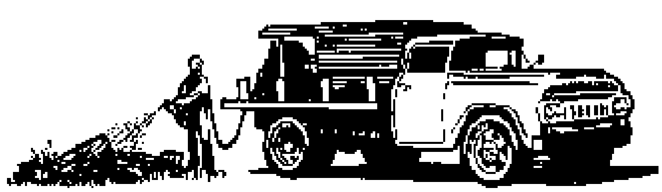
! Release the pressure if the sprayer is not to be used for more than an hour in order to conserve hoses and gaskets, which deteriorate if insecticides are held in a sprayer under pressure for prolonged periods. When possible use different sprayers for each type of formulation (e.g., wettable powder, encapsulated pesticide, emulsion, etc.) to prevent clogging when switching formulations and to ensure use of proper filters. Do not pick up or carry the sprayer by the hose. Ensure that the supporting springs at both ends of the hose are always in place to prevent crimping and breakage. Do not leave a sprayer in a vehicle for prolonged periods (e.g., overnight) in freezing temperatures.



Knapsack or Backpack Sprayer. This sprayer, as its name implies, is borne on the back of the operator with shoulder straps so that it can be carried on both shoulders. A simple diaphragm or piston pump and a mechanical agitator are mounted inside the 2 to 5 gal tank and actuated by a lever worked by the operator's right or left hand. The insecticide is under liquid pressure during each stroke of the pump. Knapsack sprayers are used chiefly in areas that are difficult to access, such as along fence lines or for mosquito larviciding in very swampy areas where it is difficult to pump a compressed air sprayer. Most have a special hand-operated lever to prime a pump to pressurize the sprayer. Depending on the model, pressures up to 150 psi can be generated, although working pressure on most is usually between 40 and 75 psi. Adjustable cone or flood jet nozzles are usually standard equipment on these sprayers.

Power Sprayers.

Originally designed for use on field crops, orchard and shade trees, and livestock, **hydraulic power sprayers** are frequently used by public health workers to apply insecticides as residual sprays to control adult mosquitoes, as larvicides to control mosquito larvae, or as area treatments to control fleas and ticks and other pests. The spray liquid is pressurized by means of a power-driven hydraulic pump fitted with suitable regulators to maintain the desired pressure - from 20 to 800 psi. The spray pattern is determined by the



pressure and the type of nozzle used, varying from a solid stream to a fine mist. Power sprayers usually have a tank of 50 to 600 gal capacity with a rotating agitator to keep insecticides in suspension. A gasoline motor or power take-off operates the piston type hydraulic pump. The power sprayers most used in public health operations are usually less than 150 gal capacity, mounted on skids, and transported on three-quarter to one and one-half ton trucks or boats, or used as smaller backpack units. These sprayers deliver a maximum of 1 to 7 gal of spray per minute and are equipped with pressure regulators to maintain the recommended pressure.

The pressure regulator is typically a large, steel ball bearing forced against a valve seat by a spring. A nut, thumb screw, or lever adjusts the spring tension to provide high or low pressure. When pressure exceeds the setting, the ball bearing is displaced and the surplus spray recirculates through the pump or is forced back into the spray tank. The power sprayer is provided with one or more hose leads to which are attached spray guns similar to those used with the small compressed air sprayers or they may be used with an orchard gun, usually provided with the sprayer purchase, which is adjustable to provide any pattern from a solid stream to a fine cone spray. The orchard gun, or a spray boom with several nozzles, may be used for treating dumps or other areas requiring heavy applications.

There is a general tendency toward using equipment heavier than is required for the operation. A large sprayer with a 500 gal tank and an output of 35 gal/min is not usually suitable for the public health operations. Small compressed air-sprayers are best for most insecticide applications in buildings and installations, whereas 50 to 150 gal power sprayers are more suitable for extensive treatment of fence lines, porches, and around outbuildings. In the latter case, the power sprayer is advantageous as it provides agitation of emulsions and suspensions, and makes frequent delays for repumping and refilling unnecessary. The 50 to 200 ft lengths of hose used with the larger truck-mounted sprayers and power sprayers cause a considerable loss of pressure at the nozzle due to friction and it is necessary to increase the pressure considerably to maintain 40 psi at the nozzle. One-half inch internal diameter hose is more suitable for long leads such as this, as it is more rugged and will cause lower friction losses than 1/4 or 3/8 inch hose.

Mist blowers work something like hydraulic sprayers, but differ in that the tank mixture is introduced into a stream of high speed air that carries the droplets to the target. Mists are used mostly outdoors for treatment of large areas, although some small mist machines are designed for limited area outdoor use. The most commonly used units are backpack models. Mist particles are usually produced by the shearing action of a high velocity, high volume air current cutting across a nozzle and atomizing the pesticide preparation as it is ejected from this nozzle. The average diameter of mist droplets is approximately 40 microns with a range of 10 to 200 microns. With this wide range in droplet size, an uneven distribution of the pesticide over the target area occurs even though the misting machine discharges the material at a constant rate.

Low Pressure Boom Sprayers. These sprayers are usually mounted on tractors, trucks or trailers. They are designed to deliver low to moderate volume (10 to 40 gal/acre) of dilute spray at 30 to 60 psi to fields, pastures, rights-of-way, etc. They are relatively inexpensive, light weight, and can be adapted to many uses, but their applicability is limited in situations where high volume or high pressure is required - to penetrate dense canopy, for example. Many low pressure boom sprayers agitate the formulation with a bypass system which may not give adequate agitation to prevent wettable powders from settling out, but mechanical agitators are available.

Aerosol and Fog Generators

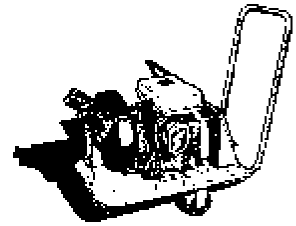
The major difference between fogs and mists is the particle size, with fog particles being much smaller. Fogs are dispensed as thermally generated aerosols through combustion exhaust systems, high-pressure steam exhausts, thermal pulse jet systems or as aerosols created by ultra low volume sprayers (cold foggers). Because of their small particle sizes, aerosols generally are not suitable for larviciding. They are effectively used for adult insect control, because the individual droplets do not settle to the ground rapidly. Since the distribution of these droplets depends on air currents and other climatic factors, care must be exercised in determining when to operate. Meteorological temperature inversion helps to hold the material down, and consistent light wind (maximum, 8 to 12 mph) serves to propel it through the habitat. Under good conditions, such as a temperature inversion with a slight breeze, an effective swath width up to 300 ft or more may be obtained with ground equipment.

Whereas some undiluted pesticides are dispensed, others are diluted with "extenders" of vegetable oils or a combination of diesel and lubrication oils. These dilutions are made in order to arrive at the optimum combination of application (dosage) rate of the active ingredient, flow rate of the machine, and droplet size for application. Powered generators are used to break liquid pesticides into aerosol and fog droplets. Reducing the liquid to aerosol droplets can be accomplished mechanically with atomizing nozzles, spinning discs, high pressure nozzles or by using heat. Thermal units usually produce fine droplets in the 5 to 10 micron range. Other non-thermal nozzles are set to produce aerosol-size droplets predominately in the 10 to 35 micron range with some as large, unfortunately because the cause the spotting damage on automobile paints, as 100 microns being produced by the cold foggers.

Thermal foggers use heat to vaporize the oil in pesticide formulations and produce fine droplets. Truck-mounted thermal aerosol generators are used in mosquito control programs - the highly visible insecticide fog rolls across open spaces , killing mosquitoes in flight as air currents move it. The thermal treatment required a large vehicle to accommodate the volume of oil and pesticide and the maximum treatment speed was 10 mph. Because of the high cost and environmental impact of the petroleum products used in this type of application, the popularity of thermal fogging has waned in recent years.

Indoors, portable thermal foggers work like cold foggers except that droplets are smaller. Special precautions are necessary indoors when thermal fogs are applied. For example, occupants must leave until the area has been adequately ventilated; pets must be removed, houseplants and aquariums must be covered, and aeration pumps turned off. Exposed foods and food preparation surfaces must be protected and pilot lights and any other open flames extinguished. Any spark can ignite a thermal fog atmosphere. The fog generators can burn surfaces that are contacted, including the operator. After treatment, food preparation surfaces and exposed utensils must be washed. Aerosol droplets will not move into spaces where air is not circulating. Ventilation from heating and air-conditioning units may need to be turned off to prevent the insecticide from being discharged to places outside the target space.

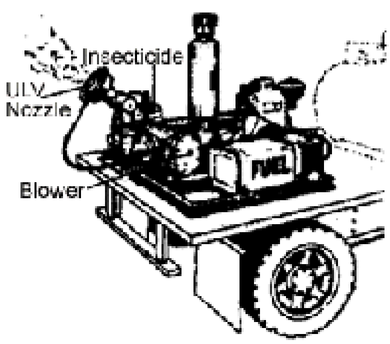
The advantages of indoor application of non-thermal aerosols have been summarized as follows: increased speed and decreased cost of application, reduced environmental contamination, lack of pesticide degradation, reduced fire hazard, and better control of particle size. Many types of non-thermal aerosol generators are now available commercially.



Ultra-low-volume Applications

Undiluted insecticides are commonly applied at extremely low dosage to control insects of public health importance. Ultra-low-volume (ULV) spraying is defined as the application of technical insecticide at a dosage rate not to exceed 64 fl oz (two quarts) per acre. The rates for public health ULVapplications are usually in the 1 to 3 fl oz range, atomized into tiny droplets, the majority measuring 5 to 50 microns (from 1/5000 to 1/500 of an inch) in diameter. These very fine droplets do not readily stick to surfaces. They disperse into open areas, kill pests in flight and can penetrate cracks and crevices. Drift of the small droplet spray cloud is desirable as it enhances the probability of reaching the target insects. Because of the low volumes of insecticide and the relatively wide dispersal of the application, the amount of the pesticide actually depositing on the ground and other surfaces per unit area is actually reduced, compared to larger droplets - resulting in lowered environmental impact.

Use of undiluted formulations results in substantial savings in money and time. As public health ULV sprays are usually applied at rates from 1 to 3 fl oz/acre, approximately 42 to 128 acres can be treated with a single gallon (128 fl oz) of technical insecticide. Savings occur not only in the cost of the insecticide, because of the reduced volume required, but also in eliminating the diluent, the mixing, and the transportation of the larger volumes of diluted spray. For example, a plane with a 100 gal tank applying conventional sprays at 1gal/acre could treat 100 acres, whereas the same plane applying technical grade insecticide at 3 fl oz per acre (or about 42 acres/gal) could treat 4,200 acres (100 gal x 42 acres/gal). This difference represents a considerable saving in loading activities, time for take-offs and landings, and by being able to remain aloft for a greater proportion of the available time when conditions are appropriate. Reduced volume also means that the size of dispensing equipment can usually be reduced. Thus, smaller and less expensive aircraft or trucks are required for transportation and application of insecticide.



Ground ultra-low-volume application. Ground application of insecticides by ULV equipment has been practiced by public health applicators since the mid-1960's. The ground ULV aerosol machine is relatively small; its pesticide tank usually has a capacity of 5 to 10 gal and is mounted on a small vehicle such as a ½ ton pickup truck. By contrast, the thermal fogger, cold fogger or ground mister machines are larger and heavier with an insecticide tank of 25 to 200 gal or more and are usually mounted on a larger vehicle, such as a 1 to 3 ton truck.

ULV applications may be somewhat less effective in heavy vegetation than thermal fogs because of the lower penetration due to the larger droplets. In some areas, car spotting (damage to automobile finishes) has occurred because of the corrosive properties of some pesticides, but generally only when droplets greater than 100 microns are present in the spray.

Greater care must be taken in handling the concentrated or technical insecticides used in the ULV method than with the diluted fuel oil formulations used in the thermal foggers, cold foggers, or misters. This is due to the possibility of exposure to higher concentrations of the chemical, particularly by spillage during loading operations, or hose rupture during application. However, equipment configuration has markedly increased applicator safety in recent years. For example, the operator can now operate the equipment remotely from the cab of the vehicle, flow controllers are available that automatically adjust for vehicle speed, and automatic flow cutoff can be programmed to occur whenever the when the vehicle stops. Some of the newer flow controllers are G.P.S.-guided and the vehicle speed, path and output can be satellite-guided

Performance requirements for ULV ground applications areas follows:

- The ULV cold aerosol nozzle for dispersal of insecticides to control adult mosquitoes should be capable of producing most droplets within the 5 to 30 micron range. Large droplets (100 microns or greater) may damage automobile paint. The optimum average median mass diameter (mmd) is between 10 and 30 microns, depending on the label directives. Determination of droplet size can be achieved in several ways, but most commonly by catching a sample of the aerosol droplets on a silicone-coated glass slide and measuring the droplets in this deposit under a high-power microscope with a micrometer.
- Tank pressure should be not less than 3 to 3.5 psi nor greater than 6 psi.
- Flow rate must be regulated by an accurate flow meter, and should not be greater than 1gal/ hr with truck speeds of 5 mph and proportionally greater volume at higher speeds.
- The nozzle should be in the rear of the truck and pointed upward at an angle of 45^o or more. Delivery of the pesticide should be interrupted when the vehicle stops.

Aerial ultra-low-volume application. Before aerial application, the applicator and equipment must meet FAA requirements, which may vary depending on whether the craft is public or private. To apply insecticides by air to insects of public health importance, the applicator should be certified in both the aerial and public health categories.

The equipment for aerial ULV is similar to that used in ground delivery in that it consists essentially of three main parts: pump, nozzles, and spray tank. The pump selected should have a capability of producing at least 150 lb psi with an output rate of 3 to 5 gpm. Positive displacement or centrifugal pumps should be used, either driven by gasoline engines or electrically - with electricity being more dependable. Centrifugal pumps require a 3/16 to 1/4 inch diameter bleed line installed on the high point of the impeller chamber to release trapped air.

When installed outside the wings, booms should be so designed that flight capabilities of the aircraft are not materially decreased. Trailing edge booms are desirable because the nozzles can be placed on the boom where the pilot can readily see them to check their performance during actual spray operations. For slower flying aircraft (90 to 125 mph), nozzle tips such as the Teejet No. 8001, 80067, or smaller, may be required. Spinning disc nozzles are sometimes used because flight speeds and pump pressure are insufficient to provide adequate particle breakup.

However, with aircraft operated at 150 mph or more, nozzles such as Teejet 8002 to 8008 are satisfactory. In most cases the flat fan type nozzles are used, although the hollow-cone swirl-jet type of nozzle may be equally satisfactory. In any event, the output of insecticide by the system needs to be determined first to insure the proper number of nozzles and appropriate orifice size to provide the desired dosage. The nozzles should be installed at a 45º angle downward and facing forward to ensure proper atomization. Diaphragm check valves set at 5 to 12 psi are used on all nozzles to ensure positive cutoff of the spray. These should be checked frequently and replaced as needed.

Aircraft spray tanks for holding technical grade insecticides are made of aluminum, stainless steel, or fiberglass. Some workers who use naled for ULV aerial application prefer fiberglass because of the chemical’s corrosive nature. The tubing from the tank to the boom should be stainless steel or plastic if naled is used and be able to withstand 2000 psi pressure.

Most ULV aerial vector control applications are conducted in a manner similar to mosquito control operations, with the following performance requirements:

- Follow the label rates and directions for correct dosage and application.
- The optimum droplet size is about 25 to 50 microns mmd, depending somewhat on the insecticide characteristics regarding volatility and viscosity. Droplets above 50 microns should be avoided since they waste material, are an inefficient size for killing mosquitoes and do not give adequate coverage. In addition, the hazard to automobile paint increases with droplet size, particularly with droplets above 100 microns (1/250 inch).
- Typical applications would be conducted at about 150 mph and 100 to 150 ft altitude, with swath widths of 300 to 700 ft. Greater swath widths have been used successfully with multi-engine aircraft flying at higher altitudes; however, droplet size and density per unit area may lose uniformity with increased swath width because the larger droplets fall faster than the smaller droplets - creating an uneven distribution. The greater the percentage of droplets below about 35 microns, the lower the application rate required, the wider the swath can be, the lower the deposition rate on the ground and the less the environmental impact.
- Application success is highly dependent on ambient wind conditions, temperature at and above ground level and other local meteorological factors, such as temperature inversion.

! The configuration of application patterns and calibration of ULV spray planes to produce specified droplet spectra and swath widths requires considerable experience and time. Some state and federal agencies and commercial companies have experienced personnel who can assist public agencies with this work. Some of this information is available from the supplier of the technical grade insecticide.

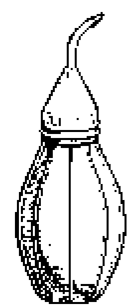
DUSTERS

Dusters apply a fine, dry layer of a powdery mixture containing a small amount of pesticide. Dust applied on porous surfaces is not absorbed - as are liquids - instead it rests there as a layer of pesticidal powder that accumulates on the hairs, legs, mouthparts, etc., of pests that touch it. But the pest absorbs the pesticide through the cuticle in the same way as liquid sprays. Additionally, if the pest ingests particles when grooming or cleaning itself, the dust can also cause stomach poisoning.

Hand Dusters.

The **foot pump** is a hand-operated plunger type blower with a container for insecticide dust. A stirrup is provided so that the pump can be held down with one foot while the operator pumps air and insecticide dust into the treatment area through a short length of hose. This equipment is useful for applying dust to rodent burrows and other enclosed harborages. Operators stand upwind from the point where the hose is inserted into the burrow to avoid inhalation of dust and take other necessary protective measures.

The **hand bellows** is a rubber cylinder (about 3 inches high) with a metal top and bottom. The top has an opening fitted with a cork and the bottom has a metal extension tube. A large coil spring touching both the top and bottom supports the device inside. Dust is placed inside the cylinder from the top. After the cork is inserted the dust is blown out through the extension tube by hand pressure on the top and bottom. This duster is used where careful placement and neatness are essential, for example, dusting crevices where cockroaches and silverfish hide or placing a small amount of anticoagulant dust in voids for mouse control.

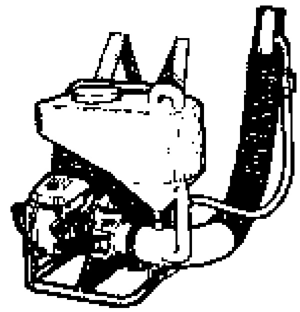


The **bulb duster** (a rubber bulb fitted with a screw-cap containing a dust nozzle, is also designed for careful indoor work. After the bulb is filled with dust, and the cap replaced, hand pressure on the bulb disperses the dust.

The **hand plunger duster** consists of a pump with a glass or metal dust chamber into which the air blast is directed to disperse the insecticide through a discharge tube as a fine cloud or as a more or less solid blast. This unit is suitable for applying mosquito larvicidal dusts to small aquatic sites, for dusting into structural openings or other similar situations, such as, to control chiggers, mites, and many insect pests. If the duster is turned so the delivery tube is beneath the dust, very heavy dust patterns are produced, suitable for making patches of dust for rodent ectoparasite control outdoors, or in outbuildings.

Power Dusters

Power dusters are used for generalized infestations, for example, for fleas under buildings, in backyards or vacant lots, or for ticks, particularly along paths or roads in parks. In the past, power dusters have been used more in the western half of the United States, power sprayers or aerosol generators are more popular in the wet or humid eastern half of this country. Ultra-low-volume aerosol machines have to some extent replaced power dusters for controlling many insects of public health importance. Most power dusters use compressed air to deliver the pesticide to large spaces or into wall voids, crawl spaces, and almost any unused space. Care should be taken to confine the dust to prevent drift into non-target spaces and to prevent combustion caused by pilot lights and flame- or spark-producing equipment. Commonly used power dusters are made of plastic with a pump cylinder similar to those used in hand-held compressed-air sprayers, or are converted from fire extinguishers and filled with compressed air. The plastic dusters release both small or large amounts of dust with better control than the fire extinguisher type.



The **small portable power duster** is designed to be wheeled or to be carried on the back of the operator. Some models completely loaded weigh from 50 to 60 lb. They consist of a hopper, a small gasoline engine which operates a radial fan, and an ir discharge nozzle into which is fed a metered amount of dust. Some models can be used to apply liquids, dusts, or granules

The **large truck-mounted power duster-mister** is used to apply dusts, granules, sprays, or mists. It has a gasoline engine, fan, hopper to hold insecticide dusts or granules, and tank to hold liquid insecticides. The high velocity fan forces the air through the large air discharge nozzle and blows the insecticide dust or granules, frequently for several hundred feet. The liquid insecticide is forced through special small nozzles into the large air discharge nozzle and blown from the machine as a spray or mist. The machine can be mounted on the body of a truck in such a manner that one person can operate it from inside the cab of the vehicle.

OTHER APPLICATION EQUIPMENT

Granular applicators are designed to apply coarse, dry particles that are uniform in size to soil or water. These spreaders eliminate the necessity of mixing the formulation with a solvent. The equipment is relatively inexpensive. There is little drift hazard. The granules themselves are less hazardous to the applicator than either liquid or dust formulations. The main disadvantages are that the granular formulation of the pesticide is relatively expensive, spreaders require recalibration for each formulation and give poor lateral distribution on side slopes. Existing equipment (such as seeders) can often be modified to spread granules. The **horn seeder** is made from a canvas bag with a tapered, telescoping wand at the lower front corner of the bag. The bag is slung over the operator’s shoulder and granules are released by swinging the wand in a horizontal motion. **Cyclone-type spreaders** are cylinders with an adjustable slot in the base, through which granules fall onto a rotating disk. They are manually operated and the granules are dispersed by centrifugal force generated by gears that are activated by turning the crank handle. The application rates can be adjusted with each of these devices by changing the openings through which the granules pass or the speed that the operator traverses. **Granular blowers** have been fabricated by modification of large mist blowers so that the granules are discharged into the air exhaust ducts, and of backpack dusters to shunt granules into the outlet side of the air system.

Currently, granulars are the most frequently used dry pesticide formulation. These are particles of bentonite, vermiculite, or other inert substances impregnated or coated with the toxicant. When applied to water as a larvicide, the toxicant is released. A related type of formulation is the microcapsule. This consists of a liquid core of toxicant and an outer shell which dissolves in water.

Compressed air projectile machines are available for projecting gelatinous capsules ("tossits") and briquets containing mosquito larvicide into small bodies of water. Inspectors can easily use them, which saves the expense of dispatching a separate control crew.

Pouring of chemicals may be of value under certain conditions. A sprinkler can is useful for mosquito larviciding in catch basins. **Dragging** bags of chemicals through water, or laying the bags in moving water may serve to control blackfly larvae or other water-dwelling forms. Calculations should be made to assure adequate control without damage to fish or other wildlife or pollution of human water supplies. **Drip cans** are superior to pouring or dragging for water treatment because the pesticide dosage can be controlled more exactly. They are better suited to use in moving water rather than in still water.

Paint brushes are very effective for applying controlled amounts of insecticides to areas where insects hide or run. They are especially suited for controlling household insects such as cockroaches and silverfish. There is less chance of damaging materials such as synthetic floor tiles or painted woodwork when applying insecticides with a paint brush than with a sprayer.

II. ACCURATE PESTICIDE EQUIPMENT USAGE

Many factors are involved in the proper delivery of pesticides to the target. The pesticide label governs the rate of application, but the user must determine exactly how to apply the pesticide, what type of formulation is best, what concentration to use, how much material to prepare, and how to calibrate the equipment to achieve these objectives. Accuracy is critical.

Preparation

Determining Size of Target Site. In some circumstances is it necessary to determine the extent of the application in terms of area or some other size parameter, and seldom is it practical to physically measure the target. To estimate ground surface areas commercial maps, charts and aerial photos can be used to provide an indirect measure. If the target site is rectangular, circular, or triangular, simple measurements and geometric formulas can be used to determine approximate size. Simply calculate the area of each and add them together to obtain an estimate of the total area. Irregularly shaped sites often can be reduced to a combination of rectangles, circles, and triangles. Currently, with Geographic Information Systems (G.I.S.) using digital photographs, very accurate measurements can be made for acreage. This capability is available in most States

For fumigants or space sprays that fill the interior of a structure, calculate the volume (cubic ft) of the enclosed space, building, greenhouse, truck, railroad car, ship hold, etc.

To apply pesticides to bodies of water (not just the surface, if the label so directs), calculate the volume of the water in the pond or lake. When the body of water is regular in shape the area calculations are fairly simple, but depth determinations may not be possible and it may be necessary to rely on educated assumptions based on what

depth information is available. If the shape or contours are irregular, calculate the parts separately and add them together to estimate the total volume.

Deciding How Much To Apply. The label has a section entitled Directions for Use, which provides information on the amount and form of the pesticide to apply. If the labeling lists a **range** of application rates, use the lowest amount that can be expected to achieve excellent control - to use less might provide an opportunity for resistant forms of the pest to be selected. Consult with industry organizations, pest or pesticide specialists, Cooperative Extension Service agents, university specialists, consultants or pesticide dealers for additional recommendations on what constitutes the optimum application rate within the label range for your situation.

Application rates may be expressed in terms of how much pesticide formulation should be applied. The instructions state how much pesticide formulation should be applied to **each unit of area or volume** in the target site, for example, 5 gal of formulation per acre or 1 lb of formulation per 100 cubic ft. Or application rates may be expressed in terms of how much pesticide formulation should be used **per volume of mixture**. In this instance the label might call for 3 tbsp of product per 5 gal of water or 1 pt of product per 100 gal of water, for example.

Often pesticide labeling and other sources express application rates in terms of how much **active ingredient** should be applied per unit of area or per volume of mixture, for example, 1 pt a.i./1,000 ft^2, or 0.5 lb a.i./500 gal water. When the application rate is expressed in this way, various concentrations may be used to achieve the proper final application rate.

Occasionally the application rate is expressed in terms of a percentage of the final formulation – **percent by volume or percent by weight**, for example. Products that are adjuvants often express the application rate in this way. Expressing application rates as a percentage allows the user to calculate the dilution correctly for whatever dilution method is being used for the formulation.

Calculations for Application. Having determined how much to apply, it is next necessary to determine how to accomplish that task with the available equipment. In the field, the application rate for a specific formulation may be related to the speed of the application equipment, the swath width from the nozzle(s), the pesticide flow or delivery rate and a number of formulation and other factors that affect each of these aspects. Standard data may be available in specialized manuals, such as the following text table, which provides the results of calculations, for example, on the number of acres treated per hour using various speeds and swath widths.

Rate of Travel	Number of Acres Covered Per Hour for Swath Widths of				
(mph)	50 ft	100 ft	200 ft	300 ft	400 ft
3	18	36	72	108	144
4	24	48	96	144	192
5	30	60	121	181	242
6	36	72	144	216	288
10	60	120	242	362	484

In order to perform the calculations needed for applications several specific values most be known, such as the number of feet in a mile (5,280) or ft^2 in an acre (43,650). Commonly used values and conversions are listed in Appendix A.

An example of a series of basic calculations may help to reveal the ease with which one determines application criteria by means of simple formulas.

Formula 1. Acreage treated.

acres treated = [miles covered (in ft) X swath width (in ft)] / [ft^2 in an acre]

Example 1: Calculate the number of acres treated when an insecticide applicator travels one mile with an effective swath width of 200 ft.

acres = (1 X 5280 X 200) / 43560 = 24.24 acres

Some field operators make this calculation even easier, but with some loss in precision, by using 42,240 ft^2 as the area of an acre rather than the actual 43,560 ft^2, and use the following formula (**1a**):

acres treated = [(miles covered X swath width (in ft)] / 8

This calculation provides an answer close to the accurate answer:

acres = (1 X 200) / 8 = 25.00

However, the easier formula actually results in a slight under-estimate of the dosage actually applied, because when the amount of pesticide that should be applied to 25 acres is actually applied to 24.24 acres, there is a 3.14% excess application. With the availability of cheap, durable pocket calculators, workers are encouraged to use the original formula rather than the quick and easy version in order to ensure compliance with the label, which is the law. In this example, the slight overdosing would be unlikely to cause damage or injury, or leave illegal residues compared to the 3% lower, accurate dosage, but it could cause fines and/or legal liability.

Formula 2. Dosage rate with liquid formulations (lbs/gal):

The dosage rate is the weight of actual technical grade insecticide applied per unit treated, e.g., pounds per acre. Formula 2 provides a simple means of converting data on liquid insecticide used and acreage covered into dosage rate.

Dosage rate = [(gal applied X insecticide in lbs/gal)] / [acres treated]

Example 2: Determine the dosage rate of malathion per acre when an area 5 miles long and 300 ft wide is treated with 40 gal of malathion containing 0.4 lb malathion per gallon of fuel oil solution? This is a standard operating procedure for fog or mist application traveling at a rate of 5 mph and dispersing 40 gal of insecticide per hour.

acres (Formula 1) = (5 X 5280 X 300) / 43560 = 181.82 acres

dosage rate (Formula 2) = (40 gal X 0.4 lb/gal) / 181.82 = 0.088 lb/acre

Use of the less precise quick Formula 1a would have estimated 0.085 lb/acre on 187.5 acres. The larger the area, the greater the discrepancy in total area estimated by the quick formula (**1a)**.

Formulas 3a & 3b. Dosage rate based on percentage of active ingredient.

The strength of the insecticide formulation is often expressed as the percentage of active ingredient. Formula 3a may be used for computing dosage rate when applying liquids, and formula 3b when applying solid formulations.

(3a) dosage rate = [(gal applied X weight/gal X % concentration)] / acreage treated

(3b) dosage rate = [(lb applied X % concentration)] / acreage treated

Example 3a: What is the dosage rate of malathion per acre when an area 5 miles long and 300 feet wide is treated with 40 gal of 6% malathion formulated from 7.1 lb/gal malathion?

acres (Formula 1) = (5 X 5280 X 300) / 43560 = 181.82 acres

dosage rate (Formula 3a) = (40 X 7.l X 0.06) / 181.82 = 0. 094 lb /acre

Example 3b: What is the dosage rate when an area 1 mile long with an effective swath width of 200 ft is treated with 5% carbaryl dust at a rate of 20 lb per mile.

acres (Formula 1) = (1 X 5280 X 200) / 43560 = 24.24acres.

dosage rate (Formula 3b) = (20 X 0.05) / 24.24 = 0.041 lbs/acre

Diluting Pesticides Correctly

Ready-To-Use or "RTU" pesticides are purchased as dilute formulations prepared at application strength. Granules and dusts are usually formulated with a low percentage of active ingredient. However, fumigants and ULV formulations are applied full strength. Other preparations come as concentrates prepared at strengths many times that needed for application. These formulations, usually wettable or soluble powders or liquids, must be diluted before use. The person preparing the mixture for application must carefully calculate how much concentrated pesticide to use and how much diluent to add. If the pesticide is not diluted correctly, the application will be incorrect. Pesticide labeling or other recommendations will tell what to use as a diluent, how much to use to dilute the formulation, and how much of the dilute pesticide to apply per unit area. Water is the most common diluent. Other diluents include solvents, such as kerosene, oil, specialized carriers, and dry ingredients, such as corn husks, sand and powders.

After determining how much to dilute the pesticide concentrate, calculate the quantity of pesticide and diluent to combine to achieve the correct amount of final mixture. Depending on the situation, you may need to know how much the equipment holds when full, how much mixture is needed to complete the job, how much mixture the equipment applies per unit area, and the size of the site to be treated. In practice, concentrated pesticides may first be diluted in a "mix tank" and then loaded into the application equipment or loaded directly into the application equipment and diluted there.

Be careful to assess how much will be required in order to make enough to do the job, with none left over (left-over pesticide may create a disposal problem if it cannot be used later). For example, suppose the label directs you to apply 3 oz of a pesticide per gallon of water to treat for cockroaches and you have a 3 gal sprayer that you estimate will hold enough to do four of the six apartments that need treatment. How much water will you put in the sprayer for the last two apartments, and how much pesticide will you add to that tank?

If 3 gallons does four apartments and all the apartments are quite similar in total area that needs treating, then you can assume that to do the next two apartments will take 1.5 gal of water, half the number of apartments that 3 gal covers (½ X 3 = 1.5 gal). The label directs you to mix 3 oz pesticide for each gallon of water. Since you have 1.5 gal of water in the tank, you will need 4.5 oz of pesticide (1.5 X 3 oz = 4.5 oz).

Another example: the label rate of a mosquito larvicide is 8 gal of formulation per surface acre and the larval infestation in your shallow, marsh pond covers an area 500 ft by 750 ft. How much product do you need to make a complete application?

First, determine how many acres of surface you must treat (500 ft X 750 ft = 375,000 ft^2). This is how many acres? (375,000 ft^2 / 43,560 ft^2 = 8.6 surface acres). If you must apply 8 gal of product per acre and you have 8.6 surface acres, then (8.6 acres X 8 gal product/acre) = 68.8 or 69 gal of the product.

Another example: perhaps the label directs you to apply a solution of 3 oz of pesticide per gallon of water to an area to control ticks or fleas in a building, including rugs and furniture. The label rate is 1 gallon of solution per 800 ft^2. First you calculate an area of 2200 ft^2 in the house where you will make the application. How much solution is needed? How much water is needed to do the job? How much pesticide do you need to do the job? Solution = (2,200 ft^2 / 800 ft^2 per gallon) = 2.75. So you need 2.75 gal of solution. Water = 2.75 gal of solution would require just shy of 2.75 gal of water, because you will be adding some pesticide. Pesticide = for 2.75 gal at 3 oz/gal the job requires (3 oz X 2.75 gal of water) = 8.25 oz of pesticide.

Now, if you had only a 1 gal sprayer, how many times would you have to mix of solution? Fill 2 times at 1 gal each (3 oz pesticide) and 1 time with 0.75 gal of water and 2.25 oz of pesticide (0.75 X 3 oz = 2.25).

Mixing, Loading, and Calibration Alternatives. Knowing the amount of the pesticide to apply is the first step. Next, it is necessary to determine how to deliver the correct amount to the target site. Depending on the type of formulation and application equipment chosen, some combination of the following three basic tasks must be conducted:

- **Mixing** . Unless the pesticide is a ready-to-use formulation or is designed to be applied full strength, it must be carefully combined with the proper amount of diluent to make the needed application-strength pesticide mixture, as described above.
- **Loading**. It may be necessary to transfer the pesticide into the equipment before it can be applied.
- **Calibrating**. For most types of application, the amount of pesticide actually delivered by the equipment must be measured and, if necessary, adjusted to comply with the label rate for the target site. Each different formulation and equipment type requires a unique concentration and rate of delivery.

However, no calibration, mixing or loading is required with pesticide formulations sold at application strength and already in the delivery equipment needed for application. These include aerosol cans, squeeze-trigger sprayers, delayed-trigger foggers, baits, shaker-can dusters, impregnated collars, bars, strips, rollers, and wiper bags. These products may be applied to the point of runoff, directed at a specific target, placed so the target contacts it, or released to fill an enclosed space. But these types of pesticides are available for use in only a few specialized situations.

Some applications require loading but no mixing or calibration. Ready-to-use pesticides may need to be loaded into the application equipment. If the equipment is a squeeze-trigger sprayer, shaker-can duster, animal or plant dipping vat, spray-dip vat, wiper applicator or a certain form of fumigant applicator, no calibration is necessary.

Other situations require calibration and loading, but not mixing. Ready-to-use formulations sometimes must be loaded into equipment that does require calibration. These include most granular and dust formulations, some liquid formulations (especially solutions) and some fumigant formulations. The pesticide is loaded without further dilution and the application equipment must be calibrated so that the correct amount of pesticide will be released per unit area or volume.

Some concentrated pesticides are first diluted and then loaded into equipment that does not require calibration. Many plant and animal dips or spray-dips, canopy sprays, and crack and crevice treatments are applied in this manner. The applicator is instructed to "cover the plant, animal, or surface thoroughly" or "apply to the point of runoff."

In most situations calibration, mixing, and loading are all part of the job - especially when concentrated pesticides are applied. The concentrate must be diluted correctly and the equipment must be calibrated correctly. Each step is crucial to applying the correct amount of pesticide to a target site. If there is an error either in dilution or in calibration, the wrong amount of pesticide will be applied.

Equipment Calibration

Label directions that specify the amount of pesticide to be applied per unit area require the applicator to carry out some very important procedures, including:

- Determination and possible adjustment of equipment delivery rate.
- Determine how much area a load of pesticide will cover.
- Determine how much pesticide to add per tank or hopper load.

An applicator’s ability to carry out these procedures is one of the most important aspects of pesticide use.

The procedure to determine the pesticide delivery rate is called calibration. Calibration is the process used to adjust the equipment to apply the proper amount of material per unit area. Proper calibration is an essential task that should not be neglected. There are many good reasons why time invested in calibration is time well spent.

- It is virtually impossible to apply a pesticide at the prescribed rate unless the equipment has been calibrated properly.
- Pesticide applications exceeding rates, and in some cases below the rates, listed on the label are illegal, .
- Chemicals need to be applied at proper rates to be effective. Too little pesticide may not provide effective

pest control. Too much pesticide may cause damage to the treated area, can result in illegal residues, and may cause adverse effects to the environment and to nontarget organisms.

Application equipment suppliers often provide charts and tables designed to help the applicator determine equipment configurations needed to obtain desired delivery rates. However, such sources of information will provide only an approximation of delivery rates. Charts and tables cannot account for equipment wear, inaccurate gauges, or speed readings, etc. Consequently, reliable determinations of equipment delivery rates are usually accomplished by calibrating the equipment.

How to calibrate the equipment. Calibration usually requires some simple arithmetic. The easiest and most accurate way to do the calculations is with a calculator. To be sure that the equipment is releasing the right amount of pesticide, take time to calibrate it carefully and correctly. Recheck it regularly to detect changes caused by wear, corrosion, and aging.

Choose equipment that is designed for the type of chemical being applied and appropriate for the size and type of application job. Equipment will not deliver the proper amount of pesticide to the target site if it is not working correctly. Check the equipment carefully to be sure that all components are clean and in good working order before beginning to calibrate. Pay particular attention to the parts that regulate the amount of pesticide being released, such

as nozzles and hopper openings. If they become clogged, not enough pesticide will be released. If they become worn, too much pesticide will be released.

Equipment that must be calibrated includes mechanical dusters, granule spreaders, hand sprayers, backpacks, booms, hand-guns, high-pressure, air blast and most other sprayers, and fumigant applicators. Although the many types of application equipment differ in the details of their operation, if the basic principles of calibration are understood, they can be applied in any situation. Study the manufacturer's instructions carefully as they explain exactly how to adjust the equipment. They often contain suggestions on such things as the appropriate rate of travel, the range of most efficient pump pressures, approximate settings for achieving various delivery rates, and types of nozzles that can be used.

If the equipment uses gravity to maintain the flow of pesticide, calibration may be fairly simple. Some equipment, such as some granule spreaders, needs to be calibrated only to adjust the rate of flow or delivery. To keep the amount of pesticide released uniform, the travel rate is kept at an even pace. With a pump or other mechanism to disperse the pesticide, it will be necessary to determine the rate of speed best suited for the particular requirements of the application. Whether hand-carried or vehicle-mounted, the speed of the equipment determines the amount of pesticide applied per unit area. The speed used during calibration should be the same as the operational speed, and for greatest accuracy the calibration should be conducted at a site similar to the operational target site. The equipment manufacturer's directions may offer a range of appropriate speeds. Knowledge of conditions at the target site and experience with the equipment will help to determine an appropriate speed.

If the application equipment has more than one nozzle or nozzle cluster or hopper, part of the calibration process is to measure the output from each to be sure that they are releasing uniform amounts of pesticide. First, check for clogging or obstructions, leaks, or worn nozzles. Then, measure the pesticide output for each nozzle (or cluster of nozzles) or hopper for a specific period of time. The output should be within 10 percent of the average of the nozzles (or cluster of nozzles) or hoppers. Replace worn or damaged nozzles or hoppers if the output is outside of the 10 percent limit. Check for uniformity of delivery using containers to collect the output. One method to achieve this is to operate the equipment for a set period of time and compare the amount of output in each container to the amount desired. The second option is to operate the equipment over a measured distance or area while calibrating, and at the end of the calibration run compare the amount of output in each container to the amount desired. If all the nozzles or hoppers are intended to release equal amounts of pesticide, the collection containers should all contain the same amount. No matter what calibration method you use, you will be measuring how much pesticide is being applied in a specific area.

The rate of application also depends partly on the particle or droplet size, texture, and other properties of the pesticide being applied. So, if the pesticide is a liquid with water as the major diluent, use water alone in the test. If the pesticide is a dust, granule, or fumigant, or a liquid diluted with a liquid other than water, you must use the actual pesticide in the test if the raw carrier is not available.

The rate of application often depends also on pressure and on nozzle size or hopper opening. The equipment manufacturer's directions are the best guide to these selections.

Once calibrated, do not assume that the equipment will continue to deliver the same rate during all future applications. Clogging, corrosion, and wear may change the delivery rate, or the settings may gradually get out of adjustment. Take time to check the calibration regularly. Be alert for possible calibration problems each time the equipment is used and notice whether the designated area is treated properly. If covering more or less area, stop the application and check both the figures and the equipment. If calculated incorrectly or if the equipment changes its delivery rate, it may be possible to catch the mistake before creating a major problem. The following paragraphs contain guidelines for some specific types of equipment

Sprayer Calibration. Proper sprayer function is essential to accurate sprayer calibration. The following procedures are recommended before calibration is carried out:

- Be sure sprayer nozzle tips are appropriate for the kind of spray application to be made.
- Thoroughly clean all nozzles, nozzle tips, and screens to ensure proper operation. Use a soft brush, not wire or any hard material. Add water to the spray tank and visually check nozzle output during sprayer operation. Discard and replace nozzle tips producing distorted spray patterns.

- If possible, check spray volume delivery of all nozzles and replace nozzle tips whose delivery deviates more than 10% from delivery rates indicated in equipment catalogs.
- If the sprayer has a pressure gauge, check it. If the gauge is rusty or of questionable accuracy, replace it. This is especially important if delivery rates are taken from spray charts or tables.

Most **compressed air sprayers** are small, hand operated units carried by the operator. Consequently, application factors such as speed, spray width, and pressure are quite variable. In short, calibrating this kind of sprayer provides a rather rough estimate of sprayer delivery, but this is certainly preferable to no estimate at all. The following is just one of several possible methods used to calibrate hand pressurized sprayers:

- Measure and mark a square area 18.5 ft x 18.5 ft, preferably on a surface which will readily demonstrate the spray pattern width (for example, a paved parking lot).
- Empty liquid spray tank residues, and using a container graduated in ounces, add 2 quarts (64 oz) of water to the spray tank.
- Pressurize the sprayer and spray the area defined by the marked square. Maintain uniform operator walking speed, nozzle height, and tank pressurization, to the extent possible.
- Depressurize the spray tank and then drain the spray wand back into the tank by holding the spray wand above the tank and opening the spray valve on the wand.
- Using the container graduated in ounces, determine the number of ounces remaining in the sprayer.
- Determine the number of ounces sprayed by subtracting the number of ounces left in the sprayer from the 64 oz originally added to the spray tank.
- The number of ounces sprayed on the defined area is equal to the gallon per acre delivery of that sprayer. For example, if the number of ounces used to cover the defined area was 36, then the sprayer is actually delivering about 36 gal/acre.
- Again, this is a rough estimate and applies only to the operator who calibrated the sprayer.

The following method is only one of many used for **Boom Sprayer** Calibration. However, this method is one of the most accurate. To apply this method the applicator should do the following:

- Select a reasonable operating travel speed for the terrain and relative durability of the spray equipment. Record the tachometer or speedometer reading and the gear / speedometer settings used to maintain the selected speed.
- Select and record the spray pressure at which the system will be operated. Adjust pressure to desired psi while the pump is operating at normal speed and water is actually flowing through the nozzles. (Minimize off target drift by operating at the lower end of a nozzle's pressure range).
- Measure total boom swath width to the nearest whole foot by spraying on a dry, flat surface, such as a parking lot or road.
- Determine the spray distance necessary to cover a full acre (43,560 ft^2). For example, if swath width is 20 ft, then (43,560 ft^2 / 20 ft) = 2,178 ft, so the sprayer must travel 2,178 ft to cover an acre.
- Measure and mark distance necessary to cover an acre.

- Using only water, fill the tank to a known level, mark that level, and mark the exact place on the ground where the sprayer is situated.
- With a running start, spray the measured distance.
- Measure the amount of water required to refill the tank to the original level.
- The number of gallons necessary to refill the tank is the sprayer delivery rate in gallons per acre.

Sprayer calibration results are valid only for the speed, nozzles, pressure, and spray width (swath) used during the calibration process. Significant changes in any one of these factors will require another calibration check. Calibrate sprayers more than once per season.

Only if you know the sprayer delivery rate and can determine the sprayer tank capacity can you determine the amount of product to add to the spray tank. For example, a label directs that 3 pt of the pesticide formulation should be applied per acre. If sprayer calibration indicates that the sprayer delivery rate is 20 gal/acre and the spray tank capacity is 100 gal, how much product should be applied with each tank load of spray?

> First, determine the number of acres each tank load will cover. If the sprayer delivers 20 gal/acre (at the speed and pressure at which it was calibrated) and the spray tank holds 100 gal, then the number of acres a tank load will cover = (100 / 20) or 5 acres. If the label directs you to apply 3 pt per acre, and a tank load will cover 5 acres, then the amount of pesticide that must be mixed per tank load is (3 pt per acre X 5 acres) = 15 pt.

However, if the area to be sprayed consists of something less than the area covered by a full tank load, a partial tank load must be mixed. For example, if the sprayer is delivering 20 gal/acre and the area to be covered is 3 acres, how many gallons of spray mix should be prepared?

> (3 acres X 20 gal/acre) = 60 gal of spray mix. If you are applying 3 pt of formulation per acre, how much formulation do you need for this application? (3 acres X 3 pt per acre) = 9 pints of product. Therefor, mix 9 pt of product in 60 gal of water to cover the 3 acres.

Most **ULV equipment** uses the air blast of a blower to break larger droplets into smaller droplets and transport them away from the vehicle. Calibration of the rate of delivery is relatively simple, being similar to standard methods. The equipment needed includes a timepiece, preferably a stop watch, and two containers - one in which to collect the insecticide and one for measuring. Obviously, when the equipment discharges only 0.5 to 4 fl oz/min (15 to 125 ml/min), the measuring container should be graduated in millimeters or tenths of a fl oz. The recommended discharge in fl oz/min for a particular insecticide is shown on the label.

To determine the **flow rate**, first disconnect the insecticide line from the nozzle and place the tip of the line in a container to collect the discharge. Then start the machine and when it is operating at the desired pressure, etc., set the flowmeter or digital readout about mid-scale of where it should be for the desired discharge. While the material is being discharged into the collection container, move the discharge line to the calibrated measuring container for a predetermined time, usually 1 minute, and then return it to the collection container. Measure and record the amount that was discharged into the measuring container. If the discharge is too much or too little, adjust the setting accordingly and repeat the procedure as many times as necessary to set the machine to dispense the recommended volume per minute. Repeat at the same setting as a check. If the discharge is satisfactory, reconnect the insecticide line to the nozzle.

With machines equipped with the older ball type flowmeter control system, the temperature of the insecticide at the time of calibration should be noted because the amount of material discharged by a particular flowmeter setting varies according to the temperature of the insecticide. If the operational temperature differs from the calibration temperature, the discharge will also differ. To correct the flow rate, the flowmeter setting will have to be adjusted. For example, when spraying malathion with a Leco generator, a 5º F difference in temperature will result in a 0.5 fl oz difference in discharge. Therefore, when discharging 2 fl oz/min there would be an unacceptable 25% error in discharge. Variations in temperature do not affect all insecticides equally. Equipment manufacturers offer guidelines that indicate proper flowmeter settings for several insecticides at various temperatures and discharge rates. In machines which have positive displacement pumps, such as the variable flow and constant flow control systems, insecticide temperature is not a factor.

Once a ULV machine has been calibrated to deliver the correct dosage, it is necessary to determine whether the insecticide is being dispersed in the correct **droplet sizes**. Instructions for testing droplet size are beyond the scope of this manual, but are given on some insecticide labels. Training for this procedure is available in most states. In general, droplets are collected on a glass slide coated with teflon and then analyzed by microscopic examination. The analysis provides information on the range of droplets sizes and on the mass median diameter (mmd) of the droplets.

Since droplet size varies with flow rate, formulation, pressure, and to some extent with temperature, it is important to check droplet size frequently. Droplet size should be reconfirmed each time the unit is put into service following repairs or maintenance, and should be verified every 100 hr of operation or as often as necessary to ensure it is producing droplets in the required range.

Since **thermal foggers** discharge much greater volumes than ULV equipment, a larger measuring container must be used. Because of the low viscosity of the dilute insecticide solution, the temperature of the solution is not a factor in determining discharge rates.

Sprayer delivery rates are easily adjusted. For example, if a calibration check indicates that the sprayer is delivering less spray than necessary, increase the application rate by slowing the travel speed, by using larger nozzle orifices, or by increasing pressure. Decrease the application rate by increasing speed, by using smaller nozzle orifice size, or by decreasing pressure. Make any major change in sprayer gal/acre by changing nozzle tips. Make the adjustments and repeat calibration runs until you achieve the desired sprayer delivery rate.

Calibrate **granular applicators** with the same material that is to be applied. The calibration method must provide a means for collecting and weighing the granules. For broadcast applicators, select a check plot of known area. Determine the swath width of the application equipment. Disconnect the spreading mechanism (if one is used) and attach a catch pan, plastic or other bag, or any appropriate container to catch the granules. Operate over the measured plot at the desired settings and travel speed with the pesticide to be applied. Catch all the material that flows through the unit. The weight of the collected granules can be converted into the amount per unit area by adjustment for the test plot size.

For example, when operated at the height above the ground and at the rotor speed you have chosen, you determine that your spreader produces a 25 ft swath. You have chosen to calibrate the spreader over a check plot of 0.25 acre. Calculate how far you would have to travel in a straight line to cover 0.25 acre with a 25 ft swath (0.25 acres X 43,560 ft^2 / acre) = 10,890 ft^2. Since 0.25 acre is 10,890 ft^2 and the swath is 25 ft, you must travel 436 ft (10,890 ft^2 / 25 ft = 435.6 ft). Measure and mark this distance, and measure the amount of granules caught in the catch pan over the 436 ft path. If 15 lb of granules are collected over this measured 0.25 acres, then you would apply (4 X 15 lb) or 60 lb over a whole acre. Adjust the setting and rerun until you achieve desired delivery rate.

Test Application after Calibration

The calibration can be checked by accurately measuring the amount in the tank or hopper, operating the equipment over the pre-measured distance while maintaining the chosen speed (if speed affects the delivery rate of the equipment), and accurately measuring the amount needed to fill the tank or hopper to the pre-application level. To figure the application rate divide the amount of pesticide dispersed by the distance or area covered. Sometimes no calculations are needed. If, for example, the label lists the application rate as "per acre" or "per 1,000 linear ft" and the output for exactly 1 acre or exactly 1,000 linear ft is measured, no calculations are necessary because if the output is correct the amount of material that was measured should equal the amount required.

However, for a number of reasons it may be more satisfactory to test a smaller site and then calculate the application rate. For example, if the label Directions for Use are for 100 linear ft or an acre, it is acceptable to use lesser (or greater) measures, say, 25 linear ft or 250 ft^2. Measure the amount applied in this smaller site and then multiply to find the rate (the amount applied to 25 linear ft multiplied by 4 equals the rate per 100 linear ft, or 250 ft^2 multiplied by 4 equals the rate per 1,000 ft^2 , or 250 ft^2 multiplied by 174.24 equals the rate per acre).

If the application equipment carries a large load (more than a few gallons of liquid or a few pounds of dry pesticide) or if the target site is relatively large (greater than an acre or 1,000 linear ft), choose a larger test site because if the test site for these types of equipment or sites is too small, measurements are likely to be inaccurate. Operating a boom or other multi-nozzle or multi-hopper equipment over a site as small as 10 feet by 25 feet, for example, would not move the equipment far enough to gauge average speed accurately.

If label directions are for 1,000 sq ft or for an acre, use a test site of at least 1,000 sq ft (a 20 x 50 ft rectangle). The output measured during the test will be the actual application rate for the 1,000 ft^2. To find the rate per acre, multiply the test output by 43.56, which is the number of square feet in an acre (43,560) divided by 1,000.

Accurate Measurement

When measuring pesticides or diluents, measure accurately. Inaccurate measurements can lead to underdosing, overdosing, too much pesticide mixture left in the tank, or a tankload of the wrong strength of pesticide mixture. Use an accurate scale to weigh out the exact amount of dry formulations. To measure a liquid formulation or diluent use measuring spoons or a tip-and-pour bottle to measure teaspoons or tablespoons, use a graduated cup or a tip-and-pour bottle to measure 1/4 cup to 1 pt, use a graduated jug or pail to measure 1 pt to 5 gal, and use a flow meter to measure more than 5 gal at a time. Do not guess how much is being adding and do not add a little extra "just to be sure”.

Do not assume that the tank is exactly the size of its claimed capacity. A "5 gallon" tank may hold more or less than 5 gal. A "100 gallon" tank often holds quite a bit more than 100 gal when totally filled. Measure the tank to be sure. Even the graduated marks on some tanks or hoppers that indicate levels of partial fill are often inaccurate. Tank capacity and gauges indicating partial fill can be checked in two ways. Fill the tank by hand with a container of known capacity, such as a measuring cup for small tanks or a 5 gal pail for larger tanks. Or attach a flow meter to a hose and measure the water as it flows into the tank. For either method, as you fill the tank, check or mark measured volumes on a dip stick or sight gauge.

If water or another liquid is used to dilute the concentrate, rinse the measuring utensils with the same diluent and put the rinsate into the mix tank. Repeat this three times to be sure all of the pesticide is removed from the measuring utensil. Measure the amount of a ready-to-use formulation carefully, too. Trying to put pesticide back into the container when you have too much left over after the application is often difficult. Add only the amount you have calculated is needed to complete the application job.

Measuring utensils, such as spoons, cups, jugs, pails and scales, that you use with pesticides should not be used for other purposes. Clean them thoroughly after each use and store them with other pesticide equipment.

III. MAINTENANCE OF EQUIPMENT

The importance of proper maintenance cannot be overemphasized. Mechanical breakdown of application equipment is not only annoying and expensive, but also can lead to liability for incorrect or inappropriate pesticide usage, damage, injury or adverse environmental impact. Failure or malfunction of surveillance equipment may disqualify data that is required for justification of pesticide application and absence of essential surveillance data can be extremely detrimental to program planning and operational activities. Because timing is often of great importance in public health pest control, equipment failure can completely destroy the value of any specific operation.

Manufacturers of insecticide and surveillance equipment usually provide information on parts and the care and maintenance. These manuals should be kept at hand and both the machine operator and the supervisor should be familiar with their contents. Follow these instructions for lubrication, operation, and maintenance. Application equipment requires diligent care if it is to be kept operating properly. Many complaints about equipment malfunction are traceable to improper maintenance.

Selection, Use and Care

Choosing the correct equipment for each job is important. Equipment should be durable, convenient to load, operate and clean, and designed to do the job needed. Cutoff valves to stop all flow or flow in any section of the spraying system should be within easy reach of the sprayer operator. Read and follow the operator's manual, which will describe how to maintain the equipment. After each use rinse out the entire system (apply the rinsate to application site). Check for leaks in lines, valves, seals and tank. Remove and clean nozzles, nozzle screens and strainers.

Be alert for nozzle clogging and changes in nozzle patterns. Before making repairs or working on problems, shut off the system, put on protective clothing and take care not to become contaminated with pesticide. Clean plugged nozzles with a brush or wooden toothpick or similar device. Do not use your mouth.

To prepare the equipment for storage, rinse and clean the system. Fill the spray tank almost full with clean water, add a small amount of new oil and coat the system by pumping this mixture out through the nozzles or handgun. Drain the pump and plug its openings or fill the pump with light oil or antifreeze. Remove nozzles and nozzles screens and store in light oil or diesel fuel.

The following general advice relates to the use and maintenance of components common to many types of equipment.

Tanks should have large openings and drains for easy filling, cleaning and draining and other outlets should be sized to the pump capacity. They should allow straining during filling and provide for mechanical or hydraulic agitation. Use tanks constructed of a corrosion-resistant material, such as stainless steel or fiberglass. If made of mild steel, tanks should have a protective lining or coating. Tanks should have a gauge to show the liquid level and a cutoff valve for storing liquid pesticide temporarily while other parts are being serviced. Protect external gauges to prevent breakage.

Pumps must have sufficient capacity to supply the required volume to the nozzles and the hydraulic agitator (if necessary), and to maintain the desired pressure. The pump parts should be resistant to corrosion and abrasion if abrasive materials, such as wettable powders, are to be used. Select gaskets, plunger caps, and impellers resistant to the swelling and chemical breakdown caused by many liquid pesticides. Consult the dealer for available options. Do not operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. Pumps depend on the spray liquid for lubrication and removal of the heat of friction and will be damaged if run dry or with restricted inlet or outlet.

Strainers (filters) remove dirt, rust flakes, and other foreign materials from the tank mixture. Strainers are your best defense against nozzle plugging and pump wear. Proper filtering protects the working parts of the sprayer from undue wear and avoids time loss and uneven application caused by clogged nozzle tips. Filtering should be progressive, with the largest mesh screens in the filler opening and in the suction line between the tank and the pump. Key these to the size of the nozzle opening. The total screen area should be large enough to prevent pump starvation. Do not use a strainer in the suction line of a centrifugal pump, but make sure the tank has a strainer to take out large trash particles and that strainers are on the filler opening, on the suction or supply line to the pump, between the pressure relief valve and the boom, and on the nozzle body. Clean strainers after each use and replace damaged or deteriorated strainers.. Nozzle screens should be as large as nozzle size permits. However, the screen opening should be less than the nozzle opening. Nozzle catalogs specify the proper screen size for each nozzle.

Select neoprene, rubber, or plastic **hoses** that have burst strength greater than peak operating pressures, have a working pressure at least equal to the maximum operating pressure, resist oil and solvents present in pesticides, and are weather resistant. Keep hoses from kinking or being rubbed. Rinse them often, inside and out, to prolong life. Store the unit out of the sun. Replace hoses at first sign of surface deterioration.

Pressure gauges monitor the function of your spraying system. They must be accurate and have the range needed for your work. For example, a 0 to 100 psi gauge with 2 lb gradations would be adequate for most low-pressure sprayers. Check frequently for accuracy. If the gauge does not zero properly, replace it. **Pressure regulators** control the pressure and, indirectly, the quantity of spray material delivered by the nozzles. They protect pump seals, hoses, and other sprayer parts from damage due to excessive pressure.

Agitators keep the spray material uniformly mixed. If there is too little agitation, the pesticide will be applied unevenly. If there is too much agitation, some pesticides may foam and interfere with pump and nozzle operation. The type of agitation necessary depends on the pesticide formulation to be used.

Hand sprayers, which generally present a greater maintenance problem than dusters, should receive the following basic attention.

- Handle it carefully, keep it clean, do not let water freeze in it;
- Strain formulations through cheese cloth prior to use to remove particles;
- Rinse thoroughly after every use and then pump 1/3 gal of clean water through it;
- Disassemble every 3 months, or at other practical intervals. Soak small metal parts in kerosene, and then clean them with a small bottle brush. Soak nozzles, wands, and tanks with trisodium phosphate solution and then clean with a scrubbing brush and rinse thoroughly. Replace worn gaskets, broken parts, etc., and reassemble. Pump two changes of water (with 1 cup of vinegar per gallon of water) through it; pump clean water through it. Oil certain parts, as in the spray gun.

With **compressed air sprayer** pumps:

- ! The piston has either a leather or a synthetic rubber cup which may require occasional maintenance. When leather cups are used, oil should be added occasionally to keep the leather pliable. Synthetic cups tend to swell when the sprayer is not emptied at night and it is then necessary to remove the plunger and let the xylene and other materials evaporate for several hours before the sprayer will operate properly.
- ! The valves are made of metal or synthetic rubber and require little maintenance and only occasional replacement.
- ! It is good practice to keep on hand a stock of all gaskets, valves, and small fittings used in the sprayers. Most manufactures produce repair kits containing the small fittings used for sprayer maintenance.
- ! After a few weeks of use the outlet hose may become weakened near the point of attachment to the spray can or cutoff valve. The hose should be cut off and remounted, as less than 6 inches will be unserviceable. The useful life of a hose may be increased by cleaning it thoroughly each night at the time the sprayer is washed out, and by storing the sprayer with hose and gun in a vertical position to prevent any sharp kinks in the hose. The hose is commonly secured to the spray delivery tube and spray gun with ordinary hose clamps. Sometimes the outlet pipe becomes clogged, particularly when suspensions are used, and requires cleaning. Much trouble can be avoided if the nipples on the delivery tube and spray gun are treated with gasket shellac before mounting the hose, and clamps are applied to give double assurance that the hose will not be blown off, possibly drenching the operator with insecticide.
- ! The strainer in the wand should be cleaned frequently, particularly if suspensions are being used. (when applying suspensions it may be necessary to remove the strainer if it becomes clogged with particles of the wettable powder). Nozzle tips are comparatively inexpensive and should be replaced when damaged.
- ! The soft gaskets and valves contained within the application wand and pump unit are critically important to the proper functioning of the sprayer. If they become worn, broken, or improperly installed, the sprayer will malfunction or constantly leak. Make sure quick-acting cutoff valves are located between the pressure regulator and the nozzles to provide positive on-off action.

Choose a **granular applicator** that is easy to clean and fill. It should have mechanical agitation over the outlet holes. This prevents clogging and helps keep the flow rate constant. Application should stop when drive stops, even if outlets are still open. Granular applicators are speed sensitive, so maintain uniform speed. Do not travel too fast for surface conditions. Bouncing equipment will cause the application rate to vary. Clean equipment as directed by the operator's manual.

Power equipment should be covered when not in use. Drain the radiator and all liquid lines before freezing weather. Keep clean and free from grit. Have regular preventive maintenance on all motors. Replace damaged parts immediately. When repairing and maintaining the sprayer: give special care to clogged nozzles, which are brass and therefore easily damaged, and either back-flush with water or use a soft-bristle brush rather than a metal tool; use the safety locknut, if there is one on the spray unit, which prevents the trigger from being accidentally activated and discharging pesticides; at the end of each workday, release the pressure and empty the liquid from the hose (into a labeled container) by holding the nozzle high and squeezing the trigger to drain the hose; rinse the sprayer and hose with water; clean the sprayer on a regular schedule. Allow only experienced personnel to operate power equipment.

The insecticide distribution system of ULV machines should be flushed with approximately one pint of isopropyl alcohol or other appropriate solvent following use.

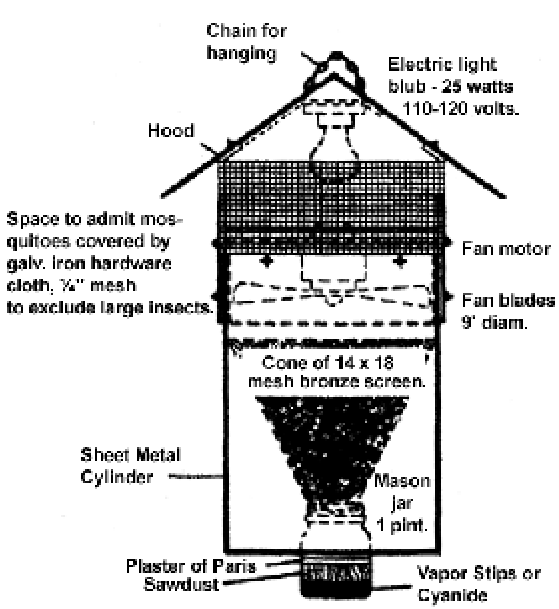
IV. MONITORING EQUIPMENT

Surveillance and inspection are critical phases of any pest control operation. To be effective in solving pest problems, the pest, the locations and extent of the infestation, and the conditions encouraging the pest problems must all be correctly identified. Therefore, professional pest management programs are based on surveillance and inspections with up-to-date and properly maintained equipment.

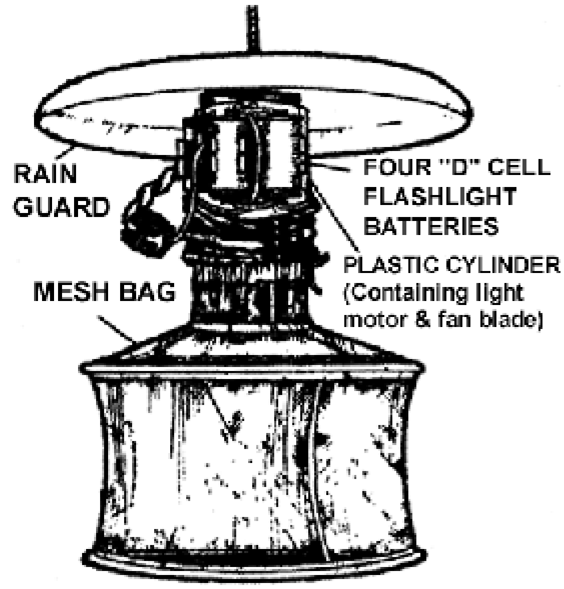
Flashlight. Though simple in form and function, the flashlight is one of the more important pieces of inspection equipment. Many insects, rodents, and other pests are secretive by nature. They hide in inaccessible or difficult-to-reach areas. Rarely do such areas contain enough light to expose hidden pests or evidence of their presence. Thus, a flashlight is an essential item, the specifications of which are dependent on the nature of the task, but should be heavy-duty, waterproof, corrosion-resistant and utilize halogen bulbs if high intensity is required. A small, metal hand mirror can extend the ability to see underneath, on top of, and behind equipment and objects. By reflecting a light beam off the mirror, visual access may be available for many out-of-sight areas, such as the inside corners of equipment, furniture, and air ducts.

Flushing Agents. A flushing agent contains a chemical that stimulates pest activity and is used to force pests from their hiding spots. Often indoor pests, such as bedbugs and roaches secrete themselves in habitats in which it is very difficult to detect their presence, e.g., hollow legs of tables, light sockets, cracks and crevices, and cabinet and wall voids. With a flushing agent, their presence may be detected.

Traps. Monitoring and surveillance traps and devices are important tools that alert you to the severity of a pest infestation and the location of hot spots. Surveillance traps can provide numerical records of pest presence and density for use before and after a control program. The New Jersey light trap and the Centers for Disease Control light trap are examples of standard devices used in pest surveillance, in this case for blood feeding insects. Surveillance devices differ from pest to pest, and are discussed in chapters that deal with specific pests.



NEW JERSEY - TYPE LIGHT TRAP



CDC MINIATURE LIGHT TRAP

Inspection and surveillance reports that list the specific pests detected provide valuable information on the extent of the infestation and clues for improvement of the intended control approach. Hand drawn surveillance diagrams giving an overview of the site are often critical. Although not necessarily artful, such an overview often clarifies the situation. These diagrams also are invaluable in helping recall details at a later date. In the case of pest populations found in permanent structures, building plans may be helpful. Computer-based software that combines site diagrams with surveillance data and other relevant information can further enhance control options and reductions in pesticide usage without sacrifice of control effectiveness.

V. CAPTURE DEVICES FOR PEST CONTROL

Traps. Traps, which have been used for pest control for centuries, can be very effective in the control of both vertebrate and invertebrate public health pests. Small animal traps range from snap traps to trapdoor containers and spring-loaded multiple catch traps. Fly traps can be sticky tape or cylinders that hang vertically, taking advantage of the fly's tendency to cling to vertical surfaces, such as, poles, strings, etc. Sticky traps in the form of small glue boards are used to catch cockroaches and rodents.

Bait Stations. Bait boxes and stations are often designed to offer both harborage and bait, which is used to entice pests to enter the stations, from which they cannot depart. Bait stations that hold poisonous baits or glue boards should be tamper-proof to protect pets and humans and other non-target organisms by restricting access to the toxic substances. In recent years, baits have become one of the most widely used formulations for cockroach and ant control. When effectively placed, they can augment other control measures or they can be used in place of more toxic formulations. The key to using these devices is proper placement.

Several products are now available that make baiting programs more convenient and effective. For rodent control, two very effective bait formulations are pastes and gels. These formulations are packaged as ready-to-use syringe-style cartridges. Bulk pastes can be loaded into the syringe, which is then loaded into a bait applicator, or applied directly to the insect habitat with, for example, a putty knife.

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Public Health Pest Control WWW site at http://www.ifas.ufl.edu/~pest/vector/