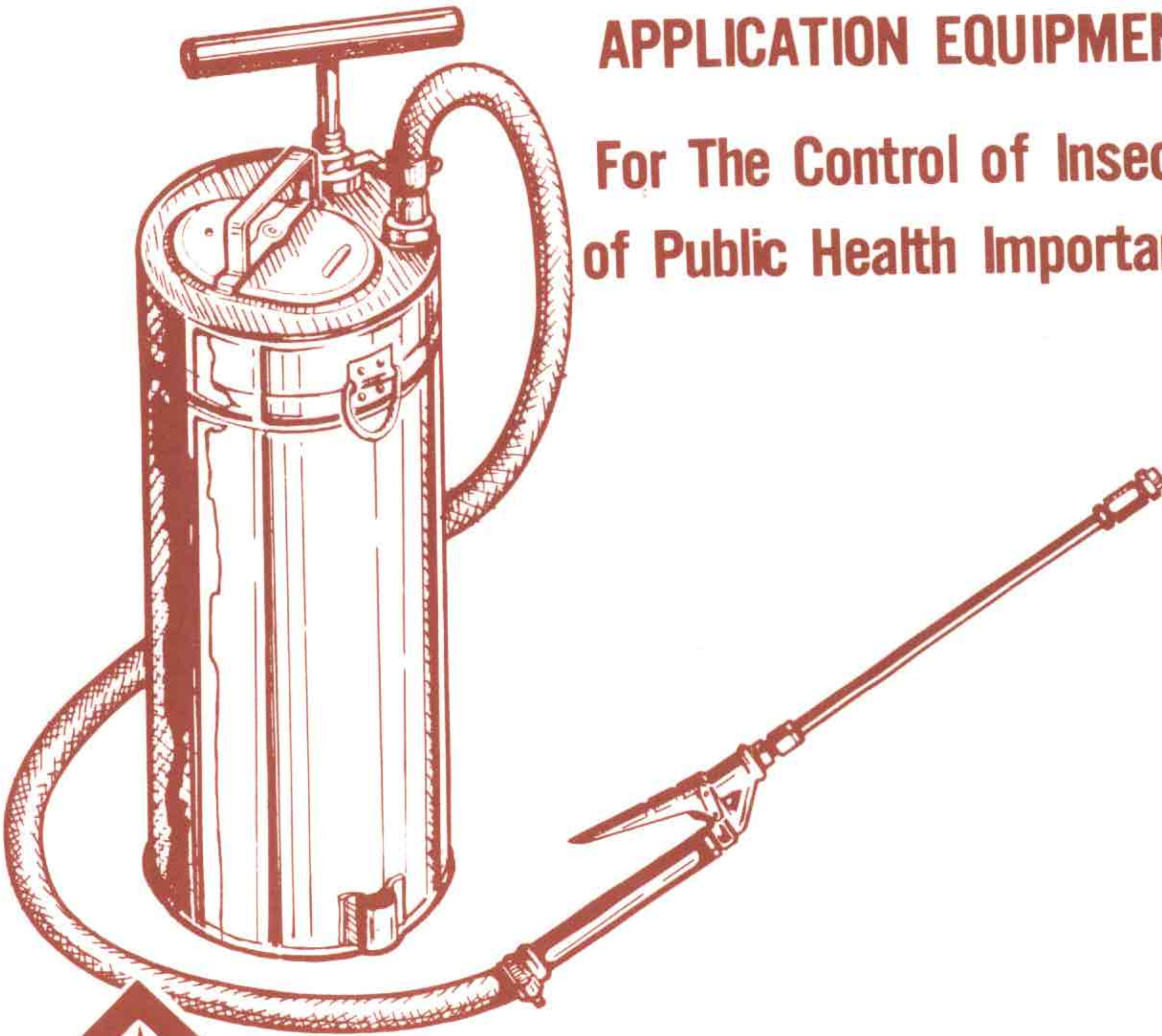
MANUAL 3

SELF-STUDY COURSE 3013-G

Vector-Borne Disease Control

INSECTICIDE APPLICATION EQUIPMENT

For The Control of Insects of Public Health Importance



4/91:5R

SELF-STUDY

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Centers for Disease Control
Public Health Practice Program Office
Atlanta, Georgia 30333

INSECTICIDE APPLICATION EQUIPMENT

For the Control of Insects

of Public Health Importance

Harry D. Pratt

and

Kent S. Littig

1974

Reprinted 1988

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL
ATLANTA, GEORGIA 30333

HHS Publication No. (CDC) 88-8396

CONTENTS

Use of trade names is for identification purposes only and does not constitute endorsement by the U.S. Public Health Service.

INTRODUCTION

Since 1940 the control of insects has been revolutionized by two outstanding developments: (1) the production of phenomenally effective insecticides, such as the chlorinated hydrocarbons, organophosphates, and carbamates, and (2) the parallel development of new types of insecticidal equipment. Many types of application equipment, such as the ultra-low-volume insecticide generators, have become available only during the past several years, so that public health workers need to examine their current needs to profit from the new developments.

Hundreds of different kinds of sprayers, dusters, aerosol generators and other devices have been designed, manufactured, and marketed. The selection of the best equipment for a vector control program is of great importance since insecticide application problems may seriously affect a program. The safe and efficient dispersal of insecticides to control insects and other arthropods affecting public health requires a knowledge of insecticide application equipment, and training in the method of applying these pesticides.

This manual describes the equipment now in use and explains the proper use of sprayers, dusters, and space sprayers. Selected references are provided for the student who seeks additional information.

METHOD OF APPLYING INSECTICIDES

Insecticide application equipment must be utilized in an approved manner to produce the maximum effect at minimum cost and to avoid hazards to humans, beneficial animals, plants, and/or nontarget organisms.

The term <u>insecticide applicator</u> includes sprayers, dusters, and other equipment used for insecticide application. Most applicators distribute insecticidal material, whether spray, dust, or aerosol, to produce a uniform coverage. <u>Sprayers and dusters</u> apply liquid or solid insecticides as contact or stomach poisons. <u>Mist and fog applicators</u> disperse the insecticide as fine particles that kill insects by contact or by inhalation through their respiratory systems.

Many formulations are available for application as liquids and solids. <u>Liquid formulations</u> are applied as liquids, sprays, or aerosols using compressed air sprayers, hand pump atomizers, aerosol dispensers, hose aspirators, pistol sprayers, hydraulic sprayers, mist and fog applicators, and aerial sprayers. <u>Solid formulations</u> are applied as dusts, granules, pellets, and baits, using shaker cans, foot pumps, hand bellows, bulb dusters, plunger and rotary dusters, and ground and aerial power dusters.

SELECTION OF INSECTICIDE APPLICATION EQUIPMENT

Four key factors should be considered when selecting insecticide application equipment:

1. <u>Will it do the job?</u> Each piece of equipment should be large enough to do the job, but not so big that it is difficult to operate. In general, it is good economy to buy the best equipment available. Simplicity of operation and ease of maintenance should be key factors in making a selection.

2. Is it safe? Safety should be a prime consideration in all insect control operations. Hazard to the equipment operator, the general public, and the environment should be considered.

3. Is it of good quality? The applicator should combine both durable construction and pleasing design that gives it a professional appearance. Poor equipment may do great harm to the public relations aspect of insect control programs.

4. Is it expensive? Cost is a primary factor. However, in the selection of equipment, a carefully thought-out, over-all analysis should be made. Purchase of low quality items may save initially, but the long-range expense cost should be weighed against such factors as durability of equipment, availability of spare parts and repair facilities, and degree of care that can be expected from workers who use it.

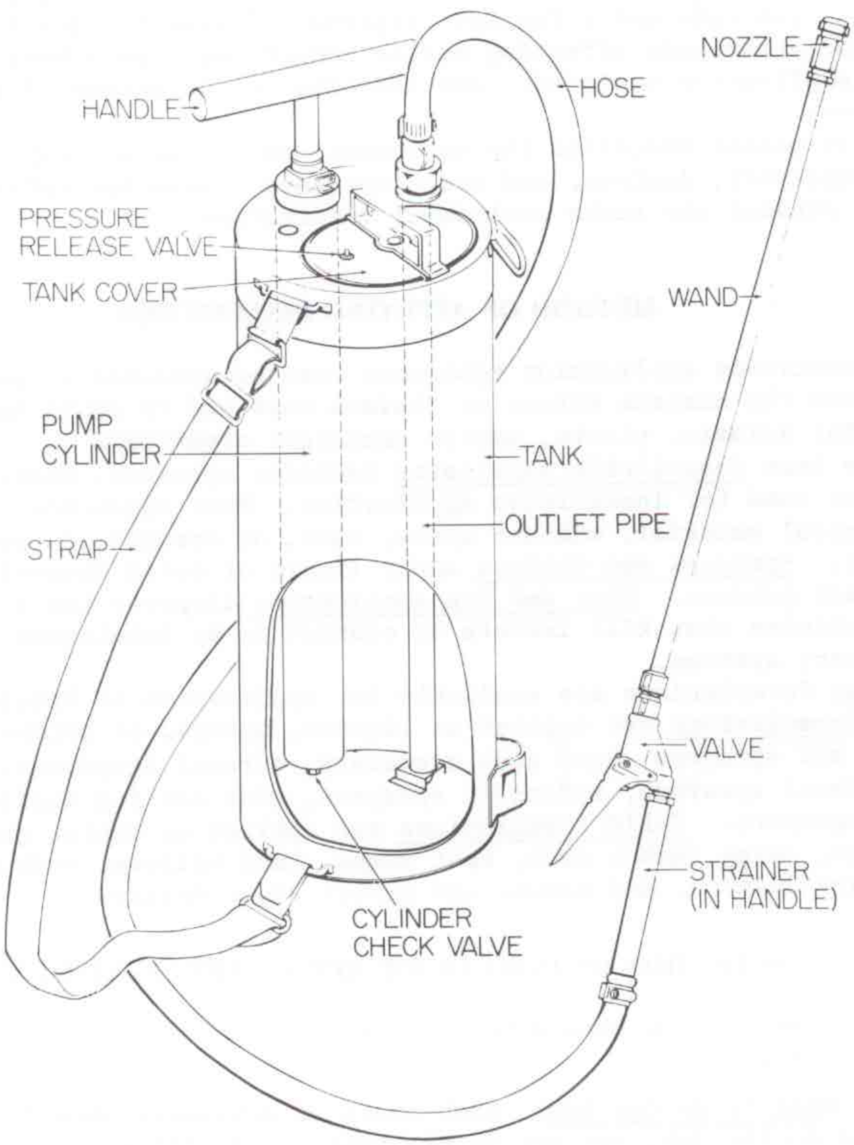


Figure 1. Compressed Air Sprayer

HAND SPRAYERS

Hand sprayers are one of the most important types of equipment used in controlling insects of public health importance. They vary in size and weight from small, hand-operated "flit guns" containing half a pint to larger, heavier pieces of equipment holding several gallons. Seven types of hand insecticide sprayers are described and illustrated in this manual: the compressed air sprayer, aerosol dispenser, hand pump atomizer, pistol sprayer, knapsack sprayer, trombone sprayer, and garden hose sprayer.

THE COMPRESSED AIR SPRAYER is the mainstay of most public health insect control projects. It is used particularly to apply residual sprays for mosquito, fly, and flea control; larvicides for mosquito and fly control; spot treatments for cockroaches, ants, ticks, and many other types of household insects; and small area treatments outside to control fleas, ticks, and other pest species. Much care must be taken in selecting high quality equipment. The compressed air sprayer (Figures 1, 2, and 3) consists of a tank, air pump, outlet pipe, spray hose, valve, wand, and nozzle.

The tank of the compressed air sprayer is made of stainless steel, brass, or galvanized steel welded or soldered into a cylinder, with bottom and head of similar material. The galvanized tanks are comparatively inexpensive and are serviceable for applying water suspensions and some insecticidal solutions. Stainless steel tanks are resistant to the corrosive effects of organic phosphorus insecticides, such as naled, and will prove economical for continued use with emulsions and other mixtures. However, stainless steel tanks can fail mechanically as readily as galvanized tanks. Some stainless steel tanks have seams joined with silver solder; they have not proved serviceable because of small leaks in the soldered seams. Electro-welded tanks are very satisfactory in this respect, but resistance welds are brittle and easily fractured. Leaks in these sprayers may be repaired with stainless steel welding rod or silver solder. Most sprayers are provided with a strap and a handle in order that they may be carried either over the shoulder or in the hand.

Some sprayer tanks are provided with a valve to release air pressure at the end of the spraying operation. If such a valve is not present, an air valve or petcock may be welded into the head where it will not be broken off by rough handling. This valve may also be used for charging the tank with compressed air in place of using the hand pump. If a sprayer is provided with no air release, it is necessary to turn the tank upside down and release the air through the spray gun, for the tank must not be opened when under pressure. Operators have been injured when releasing the head of a sprayer before discharging the compressed air. Sprayer gaskets are often damaged in this way.

Sprayers with small head openings are difficult to fill with insecticide or to clean. The entire head or large cover of some spray cans can be removed to facilitate these operations. One sprayer (Figure 1) has the cover within the tank so that the internal pressure is utilized to hold the cover tight against the sealing gasket. The pump mounting and hose connection are located on the head of the sprayer.

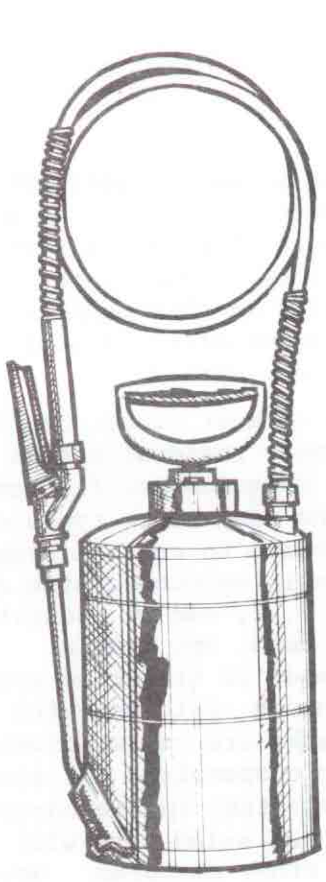


Figure 2. Compressed Air Sprayer

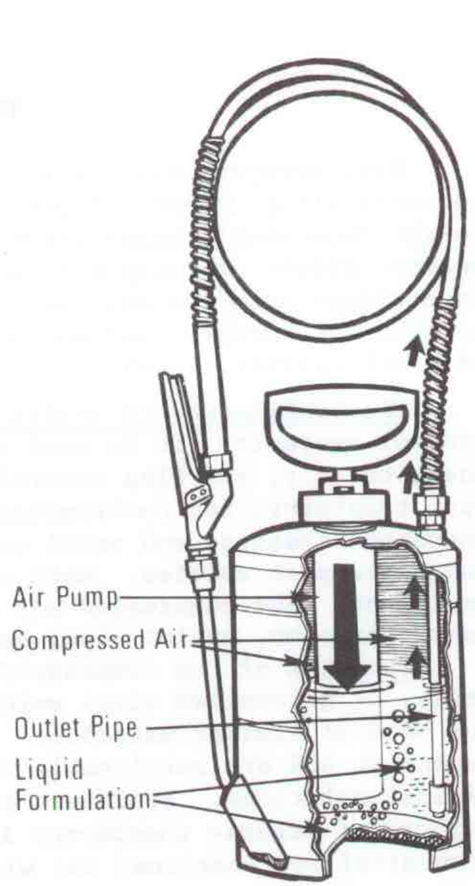


Figure 3. Compressed Air Sprayer

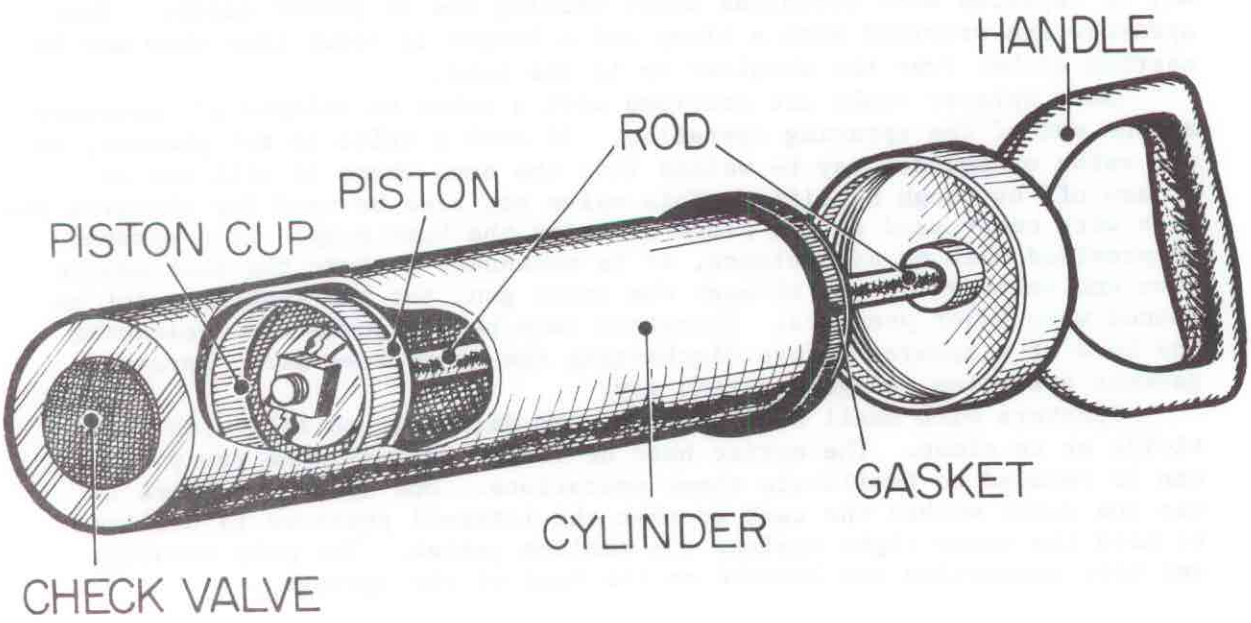


Figure 4. Air Pump of Compressed Air Sprayer

The air pump consists of a handle, a piston rod or tube, and piston which force air into the tank through a check valve in the bottom of a brass or stainless steel cylinder. 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. The synthetic cups tend to swell when the sprayer is not emptied at night and it is necessary to remove the plunger and let the xylene and other materials evaporate for several hours before the sprayer will operate properly. The pump cylinder ordinarily is fitted to the head of the spray tank with rubber gaskets if possible. The check valve at the bottom of the pump cylinder permits air to be pumped into the sprayer, but prevents air or liquid from being forced back into the pump barrel. These 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 manufacturers produce repair kits containing small parts needed for sprayer maintenance.

The outlet pipe, or dip or discharge tube, is usually firmly attached to the head and the bottom of the spray tank. The liquid passes through the pipe to the flexible hose. Sometimes the outlet pipe becomes clogged, particularly when suspensions are used, and needs to be cleaned.

The spray hose should be of synthetic rubber or plastic, 1/4" to 3/8" internal diameter, and 5 ft. in length. The natural rubber hose provided with some compressed air sprayers is soon disintegrated by the action of petroleum or xylene on its rubber lining, and is too short to permit the freedom of action required for spraying ceilings and walls. The hose is commonly secured to the spray delivery tube and spray gun with ordinary hose clamps. 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, drenching the operator with insecticide. After a few weeks of use, the hose becomes weakened near the point of attachment to the spray can or cut-off valve. It 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 spray gun, mounted at the end of the hose, consists of a valve, a wand and a nozzle. One manufacturer markets a simple ball valve that may be added to the wand to prevent the nozzle from dripping. This shut-off valve seats against the nozzle tip. Some high quality sprayers provide both a constant pressure valve on the tank and a no-drip cut-off at the nozzle tip. The valve is supplied with a trigger by means of which the insecticide stream may be cut on or off at the will of the operator.

Many of the more expensive sprayers have a strainer made of fine wire mesh inserted in the handle near the valve, as in the sprayer illustrated in Figure 1. This strainer should be cleaned frequently, particularly if suspensions are being used.

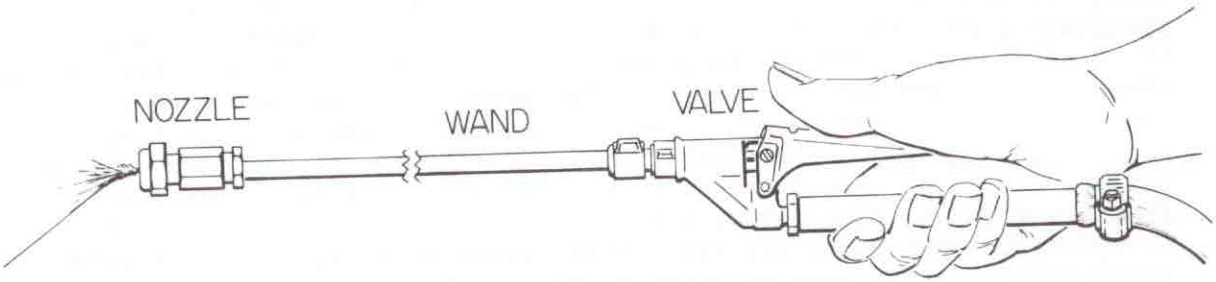


Figure 5. Spray Gun Consisting of Nozzle, Wand, and Valve

The wand is a slender metal tube extending from the valve to the nozzle. The straight wand is considered easier to use than the one with an angle near the tip. Spray wands are usually light in weight, being made of brass or stainless steel. Cast iron pipes used for this purpose are heavy and difficult to use. For spraying a high ceiling, two or more wands may be joined together or a single long one may be used to reach the upper levels.

The nozzle is the most important part of the sprayer for it determines how the insecticide will be sprayed--as a solid stream, flat spray, hollow cone, or solid cone (Figure 6). It also determines the rate of spray output at a given pressure. Nozzles are available in many types and styles, each designed with a particular purpose in mind. They may be mounted in many ways. If two or more nozzles are placed at the end of a wand the spray gun is referred to as a spray broom. The orchard spray gun has a single nozzle which 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, nonadjustable nozzles are desirable for public health insect control programs, because they may be depended upon to deliver a definite amount of insecticide per unit of time.

Nozzles are designed so that the insecticide can be applied in whatever pattern the operator desires. The primary function of the nozzle is to obtain uniform distribution of insecticides, whether the material is deposited on a surface, on water, or is dispersed into the air. Four common patterns used by public health workers are the solid stream, flat-spray, hollow cone and solid cone, as illustrated below.

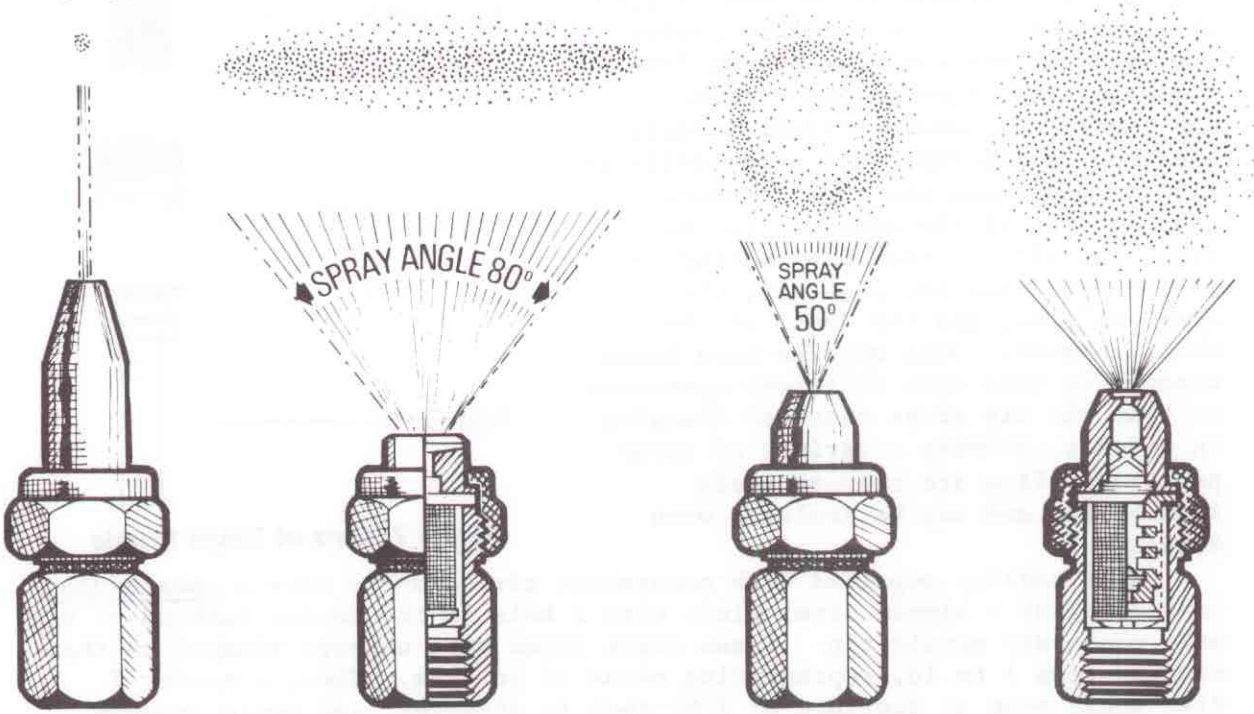


Figure 6. Types of Nozzles

1. The solid stream nozzle applies a fine stream of insecticide to treat cracks and crevices with insecticide to control cockroaches, ants, bed bugs, ticks, etc.

2. The flat spray nozzle distributes the insecticide in a thin band that issues fan-shaped from the nozzle opening. The aperture can be manufactured to produce flat spray angles varying considerably, the more common ones being 50° to 80°. This nozzle, used chiefly for residual spraying, applies insecticide on surfaces much as a large paint brush would.

3. The hollow cone nozzle is used for mosquito larviciding and treating vegetation for control of ticks and mites. Cone nozzles with large apertures are employed for surface spraying of suspensions and other materials. Most sprayers on the market are supplied with a hollow-cone nozzle for garden spraying.

4. The solid cone nozzle is used for mosquito larviciding and area treatment of vegetation.

A typical nozzle used for fly and mosquito control consists of a nozzle body, a strainer, a tip, and a nozzle cap or locking nut. Some nozzles have a whorl chamber. Many people applying suspensions find it desirable to remove the strainer because it becomes clogged with particles of the wettable powder. The spray enters the nozzle body from the wand, goes through the strainer, and leaves the nozzle through a small aperture in the tip. The spray delivery rate depends upon the tank pressure and the size of the aperture in the tip. The size of the spray particles will depend upon the pressure, the aperture size, and the depth of the whorl chamber. Some nozzles have interchangeable tips with different apertures so that the tip alone requires changing in order to produce a variety of spray patterns. Tips are comparatively inexpensive and may be replaced when damaged.

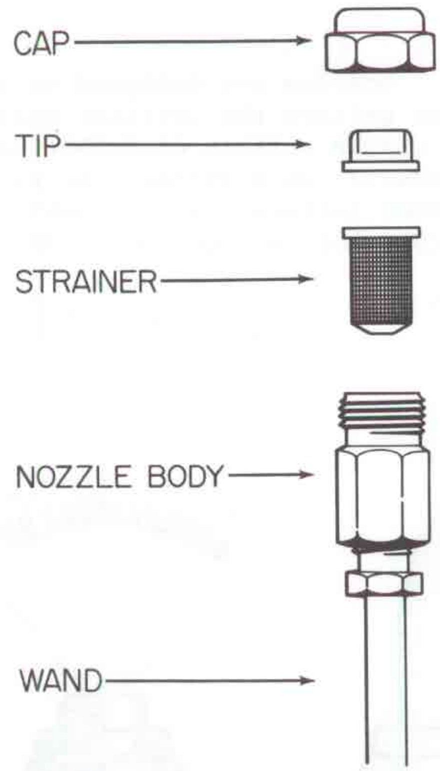


Figure 7. Parts of Teejet Nozzle

Most 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 more elaborate 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. 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: Examples are Teejet (Tables 1 and 2) and Myers (Table 3).

It is important to use the proper nozzle for each type of application. 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 (pounds per square inch). Thus, in Table 1, the 8002 nozzle used in residual spraying of emulsions on ordinary surfaces produces a flat fan spray at an 80° angle with a rate of 0.2 gallon per minute at a pressure of 40 pounds per square inch. Similarly, the 5004 nozzle used in residual spraying of suspensions on porous surfaces produces a flat fan spray with a 50° angle with a rate of 0.4 gallon per minute at a pressure of 40 psi; and the 0001 nozzle used to apply emulsions or solutions to cracks and crevices for cockroach control produces a solid stream at 0.1 gallon per minute with a pressure of 40 psi. Many pest control operators and public health workers in buildings wish 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.

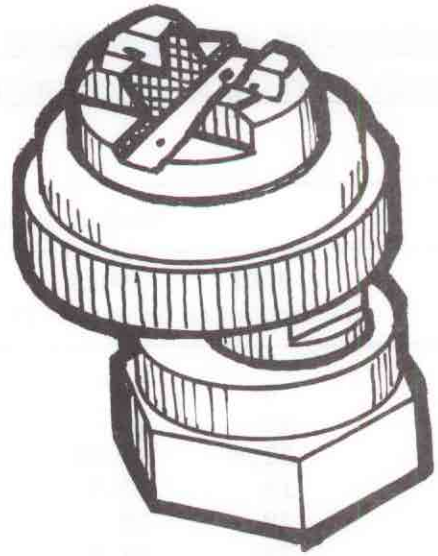


Figure 8. Multeejet Nozzle

TABLE 1 - TEEJET* NOZZLE SYSTEM

Nozzle Tip Number	Spray Pattern and Angle	GPM at 40 psi**	Use
50015	Flat - 50°	0.15	Residual spraying on very smooth surfaces
8002	Flat - 80°	0.20	Residual spraying on ordinary surfaces
5004	Flat - 50°	0.40	Residual spraying on porous surfaces
0001	Solid - 0°	0.10	Cockroach control
TG1	Hollow cone 60°	0.20	Mosquito larviciding. Residual spraying 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 - 50°	0.15	Residual spraying on very smooth surfaces
730039	Flat - 73°	0.039	Mosquito larviciding
000021	Solid - 0°	0.021	Cockroach control in fine homes or hotels
0001	Solid - 0°	0.10	Cockroach control

* Spraying Systems, Inc., Wheaton, Illinois, 60187

** Gallons per minute at 40 pounds per square inch pressure.

*** This nozzle has four different apertures.

TABLE 2 - APPLICATION RATES FOR TEEJET NOZZLES AT VARIOUS INSECTICIDE CONCENTRATIONS

Insecticide Concentrations	Teejet Nozzles 8001	50015	8002	5004
	(insecticide deposit in milligrams/ft.^{2})			
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

Note: Surfaces treated at rate of 190 square feet per minute with pressure of 40 pounds per square inch.

The spray pattern depends primarily on the type of nozzle used and secondarily on the air pressure in the sprayer tank. The spray tank is filled two-thirds to three-quarters full of spray liquid. The air should be compressed to about 55 psi (pounds per square inch) 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, but not constant, pressure of 40 psi is maintained to produce the delivery rate and spray characteristics for which many nozzles are designed. Spray operators soon learn to judge the correct pressure for spraying by observing the spray pattern.

A man being trained to treat surfaces with the 8002 nozzle should be taught to spray at 190 sq. ft. per minute. If a 2.5 per cent malathion emulsion is being used the resulting dosage will be 100 milligrams per square foot. If the nozzles or nozzle apertures are changed, other conditions remaining the same, this man would then be applying insecticide at the wrong rate. In cases where more or less insecticide per sq. ft. is desired, it is necessary to increase or decrease the concentration of the spray in order that the operator may continue his usual uniform speed of application. The 5004 nozzle, for example, can be used to apply 1.25 percent wettable malathion at the rate of 100 milligrams per square foot. The insecticide concentration is reduced by one-half in this case to compensate for the nozzle delivery rate which is twice that of the 8002 nozzle, see Table 2. The 5004 nozzle should be held about 24 inches from the wall to give the same coverage as the 8002 at 18 inches distance.

TABLE 3 - MYERS* NOZZLE SYSTEM

Nozzle Tip Number	Spray Pattern and Angle	GPM at 40 psi	Use
5741A - #2	Mist	0.08	Mosquito larviciding
6530A - #2	Flat - 80°	0.16	Residual spray on smooth surface
6530A - #3	Flat - 80°	0.35	Residual spray on porous surface
6690A - #2	Adjusts from mist to solid stream	0.000 0.16	Mosquito larviciding cockroach control

* F.E. Myers & Bros. Co., Ashland, Ohio.

THE AEROSOL DISPENSER, or "bug bomb," is more widely used by the general public than any other type of insecticide applicator. In 1971, 109 million of these small, hand-operated aerosol dispensers with insect sprays were sold *(10)*.

Insecticide aerosol dispensers are sold in two general types: (a) small, low-pressure, disposable "bug bombs" used by the average householder, and (b) larger, high-pressure, refillable aerosol dispensers used on some public health programs and by pest control operators.

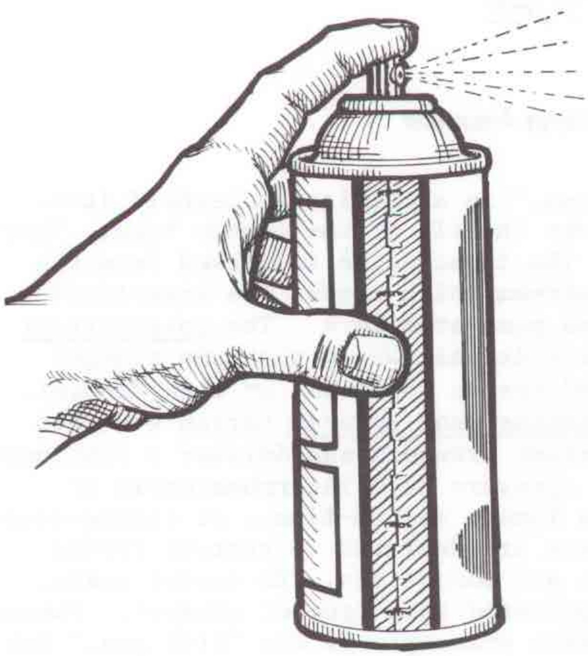


Figure 9. Small, Disposable Aerosol Dispenser

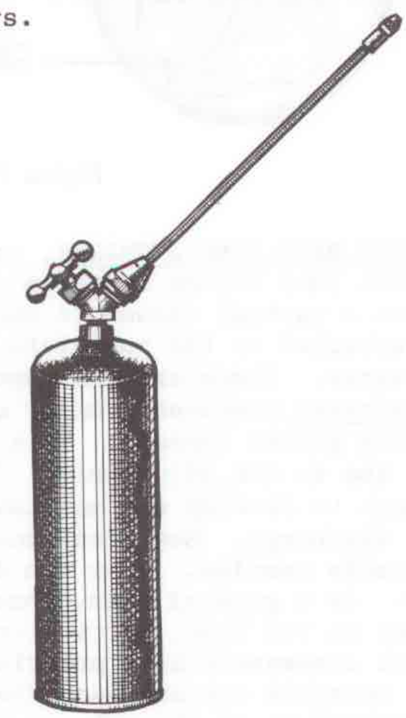


Figure 10. Large, Refillable Aerosol Dispenser

The small, low-pressure aerosol bomb consists of a can with a discharge valve and nozzle at the top, and a tube extending from the valve to the bottom of the can. The insecticide in a concentrated oil solution is mixed with a propellent (usually the nontoxic gas Freon in liquid form) and placed in the can at the time it is assembled. When the discharge valve is pressed, propellent gas within the can forces the insecticide-propellent mixture through the nozzle and it is atomized into spray.

One of the most common types of bug bombs for flies and mosquitoes contains pyrethrum, allethrin, or synthetic pyrethrum for quick knockdown, a synergist such as piperonyl butoxide, and a synthetic insecticide such as methoxychlor for the kill. Other aerosol dispensers contain different chemicals to kill cockroaches, ants, and other household insects. One bomb, manufactured to throw a fine stream for 10 to 20 feet, is used to spray nests of stinging insects such as wasps and hornets from a safe distance.

Always store aerosol dispensers in a cool place and never throw used ones into an incinerator.

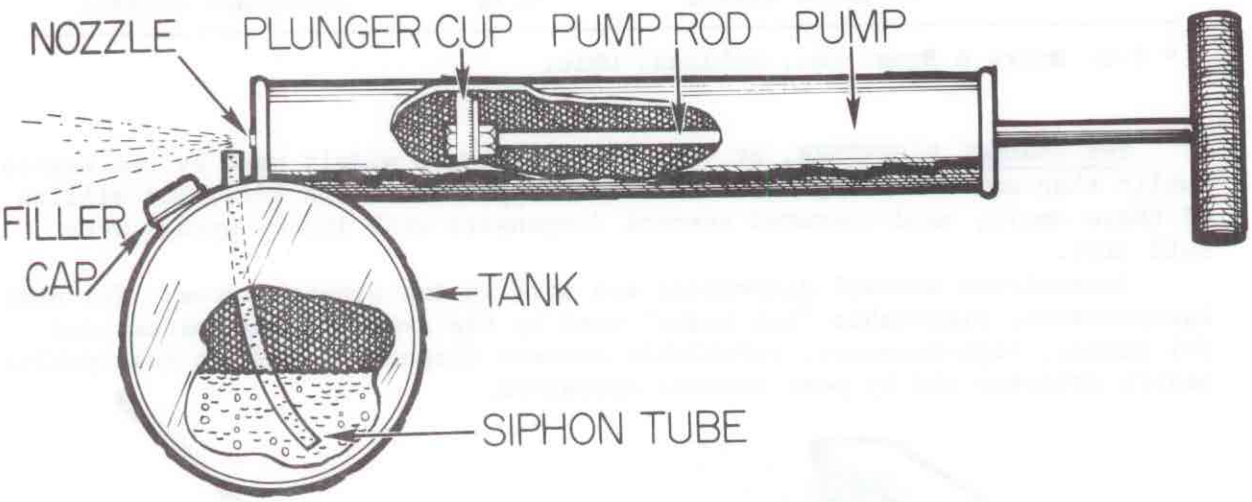


Figure 11. Hand Pump Atomizer

THE HAND PUMP ATOMIZER, or "flit gun," is a familiar household item. A piston pump forces a stream of air over the tip of the siphon tube. This creates a partial vacuum in the tube. The insecticide is sucked from the tank attached to the pump into the airstream which breaks the insecticide into spray. There are two types of hand pump atomizers. The intermittent hand sprayer produces a spray of insecticide only while the pump plunger is being pushed forward. This type produces an atomized, or fine droplet, spray and is not adjustable. The continuous hand sprayer forces air into the tank to develop and maintain a constant pressure and deliver a continuous spray discharge. Most continuous hand sprayers have interchangeable or adjustable nozzles. They can deliver a fine-, medium-fine-, or coarse-droplet spray. As a general rule, these sprayers are designed to control flying insects in the home, particularly flies and mosquitoes. In recent years, aerosol dispensers have practically supplanted this type of sprayer. Pneumatic paint sprayers operate upon the same basic principle as the "flit gun," but are powered by an electric or gasoline motor. They are sometimes used for space spraying in larger buildings where hand equipment is inadequate.

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 on the gun. It is especially valuable when small amounts of solution or emulsion need to be applied to cracks and crevices in buildings for cockroach and ant control. Pistol sprayers are especially designed to resist corrosive chemicals. A plastic container has been used to apply small amounts of insecticide to collections of water in small containers, such as tin cans, saucers under flower pots, old tires or water drums. They were used extensively on the *Aedes aegypti* eradication program and may play a part in many urban mosquito control programs.

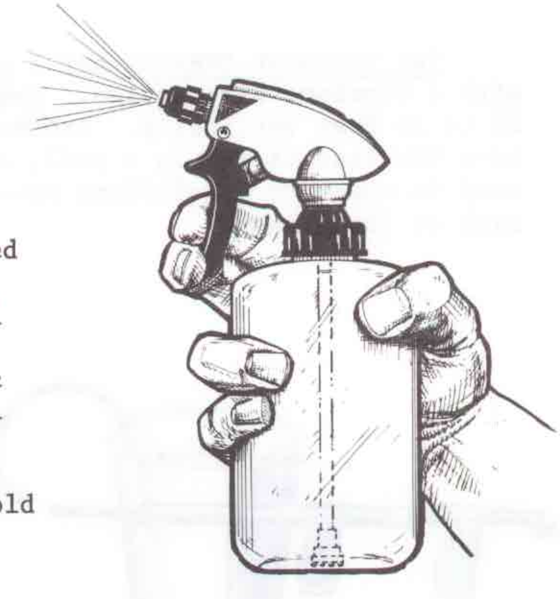


Figure 12. Pistol Sprayer

THE KNAPSACK SPRAYER, borne on the back of the operator, has 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 tank and actuated by a lever worked by the operator's right hand. The insecticide is under liquid pressure during each stroke of the pump. Knapsack sprayers are used chiefly in treatment of small gardens, and to a lesser extent for mosquito larviciding in very swampy areas where it is difficult to pump up a compressed air sprayer. Adjustable nozzles are usually standard equipment on these sprayers.

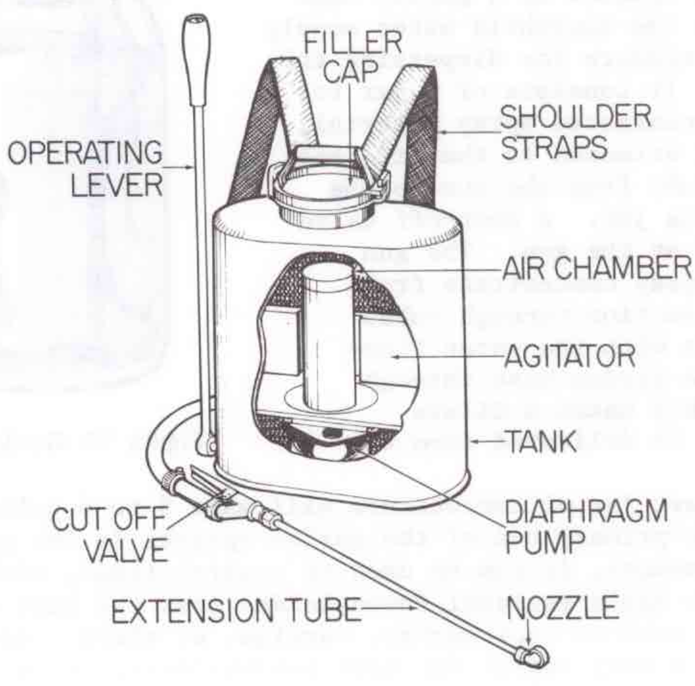


Figure 13. Knapsack Sprayer

THE TROMBONE SPRAYER has a plunger and cylinder moving on each other with a trombone-like action. Some types can throw a stream of insecticide 20 to 30 feet vertically. Trombone sprayers used around buildings usually have the insecticide in a pail, as shown in Figure 14, while other types used in mosquito larviciding have the insecticide in a tank carried on the back of the sprayman.

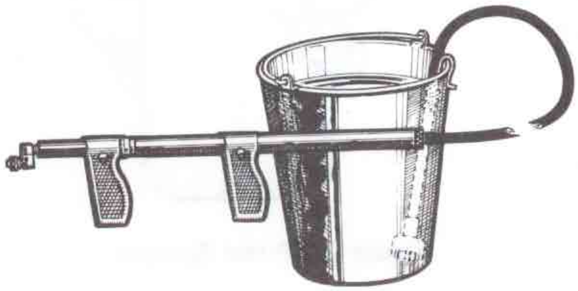


Figure 14. Trombone Sprayer

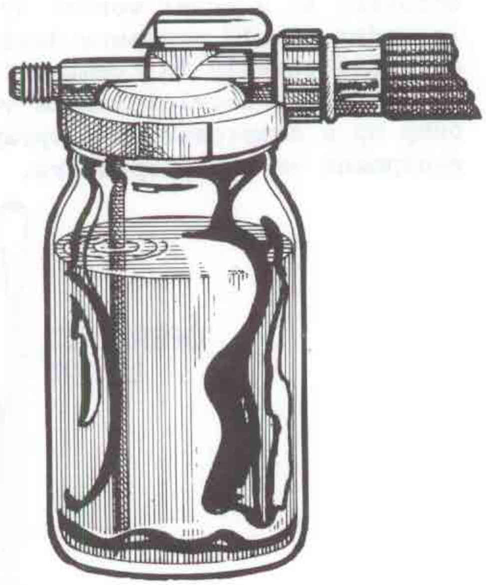


Figure 15. Garden Hose Sprayer

THE GARDEN HOSE SPRAYER is designed to connect to a garden hose and utilize the household water supply and water pressure for dispersing the pesticide. It consists of a jar for holding concentrated spray material, a spray gun attached to the lid, and a suction tube from the gun to the bottom of the jar. A shut-off valve is provided at the gun. The gun draws the spray concentrate from the jar by suction through tubes and mixes it with the water flowing from the garden hose through the gun. This makes a dilute spray which is delivered from the nozzle.

A 1-quart jar of concentrate will make 5 to 6 gallons of dilute spray. Although the primary use of the garden sprayer is for garden, lawn, and shrubbery insects, it can be used to control fleas, ticks, and chiggers in yards, or to apply residual insecticides near the base of buildings to keep out insects such as cockroaches, earwigs, or mites. Although this type of sprayer is very useful for many householders, it is limited to the area that can be reached with the garden hose.

HAND DUSTERS

THE HAND SHAKER is ideal for placing insecticide on high or difficult to reach areas. A large shaker which holds 9 pounds of insecticidal dust has been used for dusting exposed rat runs along the base of walls and foundations to kill rat ectoparasites such as the oriental rat flea which transmits organisms that cause plague and murine typhus. This shaker is rectangular with a handle attached to one side. The detachable lid has a screen end to sift the insecticide dust when the duster is shaken. Small one- or two-pound shakers may be used for dusting rat runs not accessible to the large shaker. A long handle may be attached to the duster to facilitate the treatment of overhead beams and rafters. If the shaker is fitted with 16- to 20-mesh screen, or a perforated lid, a baffle is not necessary to keep the dust from being dispensed in too great quantities.

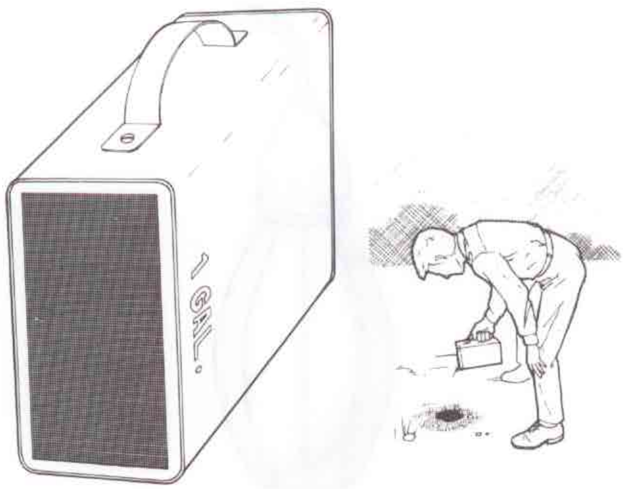


Figure 16. Hand Shaker

THE FOOT PUMP is a hand-operated plunger type blower with a container for insecticide dust or fumigant. A stirrup is provided so that the pump can be held down with one foot while the operator pumps air and insecticide into the treatment area through a short length of hose. The one- and five-pound capacity foot pump are designed for applying calcium cyanide to rat burrows to kill both rats and rat ectoparasites. This equipment is useful for applying dust to rodent burrows and other enclosed harborages. Operators should wear a gas mask, long-sleeved shirt and rubber gloves when using calcium cyanide in a foot gun. They should always stand upwind from the point where the hose is inserted into the burrow to avoid inhalation of dust or cyanide gas.

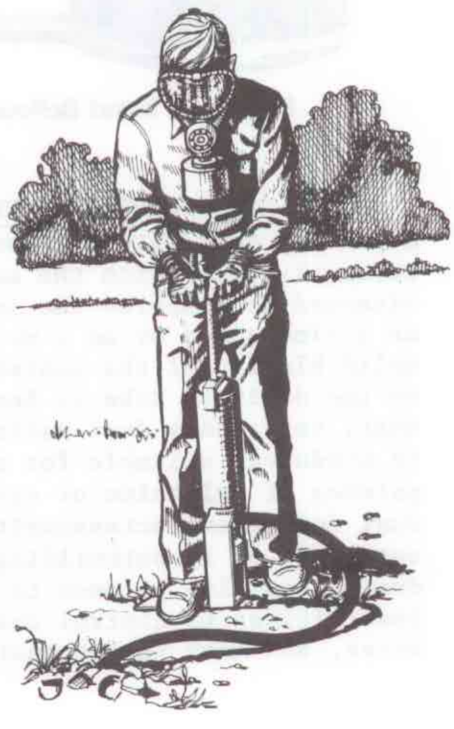


Figure 17. Foot Pump

THE HAND BELLOWS is a rubber cylinder (about 3" tall) with a metal top and bottom. The top is open and fitted with a cork. The bottom has a metal extension tube. A large coil spring touching top and bottom supports the device inside. Dust is placed inside the cylinder from the top, the cork is inserted and 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, dusting crevices where cockroaches and silverfish hide, or placing a small amount of anticoagulant dust in voids for mouse control.

THE BULB DUSTER is also designed for careful indoor work. A 4" rubber bulb is fitted with a screw-cap containing a dust nozzle. After the bulb is filled with dust, and the cap replaced, hand pressure on the bulb disperses the dust.

Figure 18. Hand Bellows

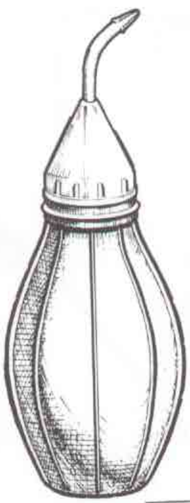


Figure 19. Bulb Duster

THE HAND PLUNGER DUSTER consists of an air pump with a glass or metal reservoir into which the air blast is directed to disperse the insecticide as a fine cloud or as a more or less solid blast. If the duster is turned so the delivery tube is beneath the dust, very heavy dust patterns will be produced, suitable for making patches of malathion or carbaryl dust for rodent ectoparasite control outdoors, or in outbuildings. This duster can also be used to apply insecticides to control chiggers, mites, and many insect pests.

Figure 20. Hand Plunger Duster

THE KNAPSACK DUSTER is a large bellows duster which may be mounted on the back, similar to the knapsack sprayer. It consists of a large circular tank, the top of which forms the bellows actuated by the up-and-down motion of a side lever. Dust is inserted through a cover on the back of the machine. This type of machine may be used for mosquito larviciding or area application of dust for flea, tick, or chigger control.

THE ROTARY HAND DUSTER has a 5 to 10 pound capacity hopper from which dust is fed by a mechanism into a fan case. When the crank is turned, the fan blows the dust through a long tube. Most dusters may be adjusted to deliver from 5 to 20 pounds of dust per acre under normal conditions. Rotary dusters are used effectively for applying insecticides for controlling fleas, ticks, and other ectoparasites around premises, and for applying dusts as mosquito larvicides. Most rotary hand dusters are sold with a fan-shaped tip to give a broad band of dust for mosquito larviciding or for area treatment in flea, tick, or chigger control. This fan-shaped tip can be removed if the duster is to be used for applying dust to rodent burrows to kill ectoparasites.

Figure 21. Rotary Hand Duster

THE GRANULE APPLICATOR occurs in two main types: the alfalfa or grass seeder and the "sling" seeder. Both types are used to apply granules to control mosquito larvae, particularly in areas with intermittent pools.

THE CYCLONE, ALFALFA, OR GRASS SEEDER consists of a rotary slinger plate operated by gears and a hand crank, and a cylindrical metal hopper or cloth bag granule holder. Buzicky *(2)* states that "when being used in tall grass and cattails the gears and rotating plate get clogged with vegetation which then causes breakdowns. A protective sheet of metal can be mounted parallel to and below the slinger plate and ahead of the latter, to divert the vegetation away from the moving parts."

THE "SLING" SEEDER, or horn seeder, consists of a teardrop-shaped granule bag hung by a webbing strap over the right shoulder. Attached to the lower small end of the bag is a tapered metal tube about 3 feet in length. In the base of the tube is an adequate gate to regulate the flow of granules. Granules flow by gravity from the bag into the basal part of the hollow tube. The operator then whips the tube back and forth and the granules are discharged by centrifugal force from the tube. A skillful operator can make a very even application of granules. This applicator has the advantage of having no moving parts, so maintenance is minimal.

Figure 22. Cyclone Seeder

Figure 23. Sling Seeder

POWER SPRAYERS

HYDRAULIC POWER SPRAYERS, originally designed for use on field crops, orchard and shade trees, and livestock, are frequently used by public health workers to apply insecticides as residual sprays to control adult mosquitoes and flies, as larvicides to control mosquito and fly larvae, and as area treatments to control fleas, ticks, and chiggers. The spray liquid is pressurized by means of a power-driven hydraulic pump with suitable regulators provided to maintain the desired pressure. Pressures range 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. The power sprayer has a tank of 50 to 600 gallons capacity, with a rotating agitator to keep insecticides in suspension. A gasoline motor or power take-off operates a piston-type hydraulic pump. The power sprayers most used in public health operations are small outfits of not more than 150 gallon capacity mounted on skids and transported on three-quarter to one and one-half ton trucks. These sprayers deliver a maximum of 1 to 7 gallons of spray per minute and are provided with pressure regulators in order that the recommended pressure of 40 psi may be maintained.

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 that desired, 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. These sprayers may also be used with the orchard gun ordinarily purchased with the sprayer. The orchard gun is adjustable to provide any pattern from a solid stream to a fine cone spray. The orchard gun, or a spray broom with several nozzles, may be used for treating dumps or other areas requiring heavy applications.

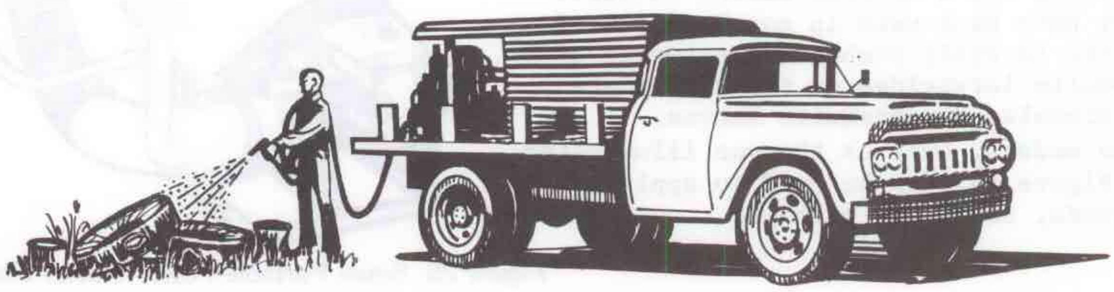


Figure 24. Hydraulic Sprayer

There is a general tendency toward using equipment heavier than is required for an operation. A large sprayer with a 500-gallon tank and an output of 35 gpm is not suitable for the usual public health operations. Small compressed air sprayers are best for most insecticide applications within the home, whereas 50- to 150-gallon power sprayers are more suitable for extensive treatment of fences, porches, and outbuildings. In the latter case, power sprayers are advantageous for they provide agitation of emulsions and suspensions, and make frequent delays for repumping and refilling unnecessary. A 50 to 200 ft. length of hose is used with the larger truck-mounted sprayers and power sprayers. These long hoses cause a considerable loss of pressure at the nozzle due to friction, and it will be necessary to increase the pressure considerably to maintain 40 psi at the nozzle. The 1/2" internal diameter hose is more suitable for long leads such as this, as it is more rugged and will cause lower friction losses than the 1/4" hose.

POWER DUSTERS

Power dusters are used to kill adult and larval mosquitoes; flies, particularly at dumps or disaster areas; generalized infestations of fleas under buildings, in cellars, or in backyards or vacant lots; and ticks and chiggers, particularly along paths or roads in parks. In the past, power dusters have been used more in the western half of the United States, and power sprayers or aerosol generators more in the wet or humid eastern half of this country. In the future ultra-low-volume aerosol machines will probably replace power dusters for controlling many insects of public health importance.

THE SMALL, PORTABLE POWER DUSTER is designed to be carried on the back of the operator. Some models completely loaded weigh from 50 to 60 pounds. They consist of a hopper, a small gasoline engine which operates a radial fan, and an air discharge nozzle into which is fed a metered amount of dust. They have been used in northern United States to apply prehatch treatments of mosquito larvicides or to apply dusts or granules for mosquito larvae. Some models, such as the one illustrated in Figure 25, can be used to apply liquids, dusts, or granules.

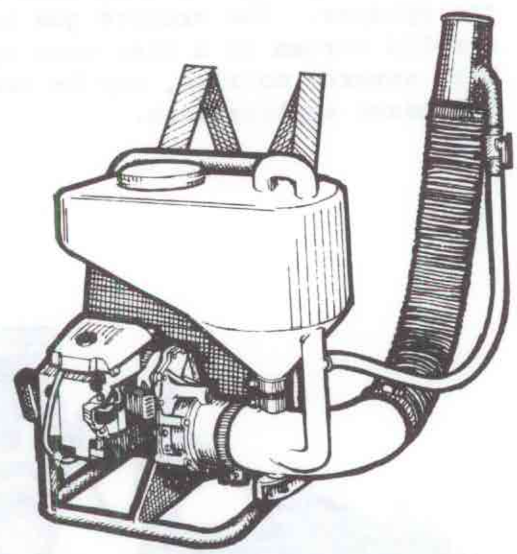


Figure 25. Small Portable Power Duster-Mister

THE LARGE, TRUCK-MOUNTED POWER DUSTER-MISTER can be used to apply insecticide dusts, granules, sprays or mists. It has a gasoline engine, a fan, a hopper to hold insecticide dusts or granules, and a 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 into the control area, frequently for several hundred feet or yards. 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 large machines can be mounted on the body of a truck in such a manner that one man can operate it from the cab as he drives the vehicle. Many of the large duster-misters have a self-starter. In the past, these large power duster-misters have been used effectively for fly and mosquito control after floods or in disaster areas.

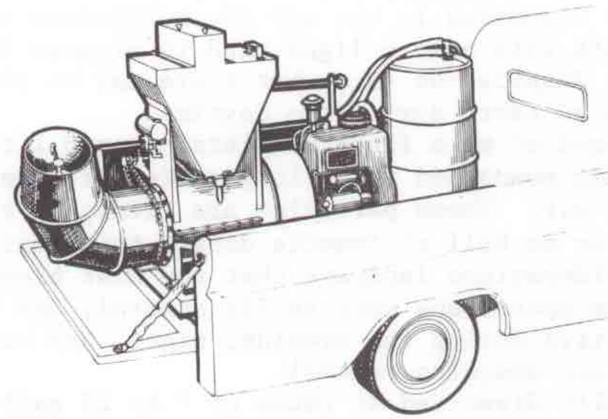


Figure 26. Large Truck-Mounted Power Duster-Mister

THE BOAT-MOUNTED POWER DUSTER is used in some mosquito control districts. These machines have several advantages: they can be used from the open-water side of mosquito-breeding places; they have a wide effective swath over water with only floating or low surface vegetation; and they do not require access roads in difficult, swampy terrain.

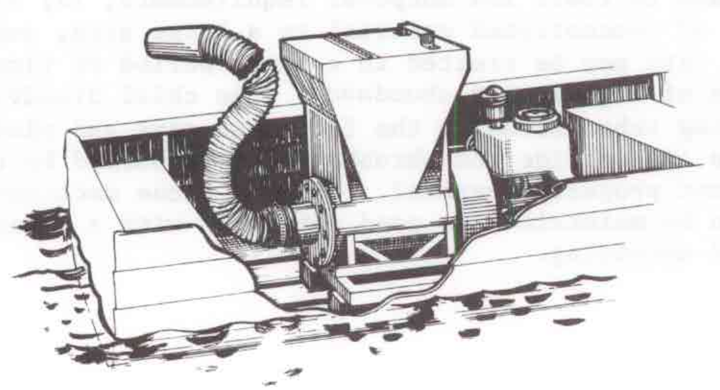


Figure 27. Boat-Mounted Power Duster

MIST AND FOG APPLICATORS

Mist and fog applicators are used for space spraying with contact insecticides. Mist and fog machines control insects by the same principle as that utilized by hand sprayers and aerosol dispensers--contact killing.

In urban space spraying for mosquito and fly control, the city block is the unit treated. The machines are operated in the streets and through the alleys to produce a complete coverage of insecticide, taking advantage of the wind. In general, mist is directed over housetops, while fog is kept as near the ground as possible (See Figure 28).

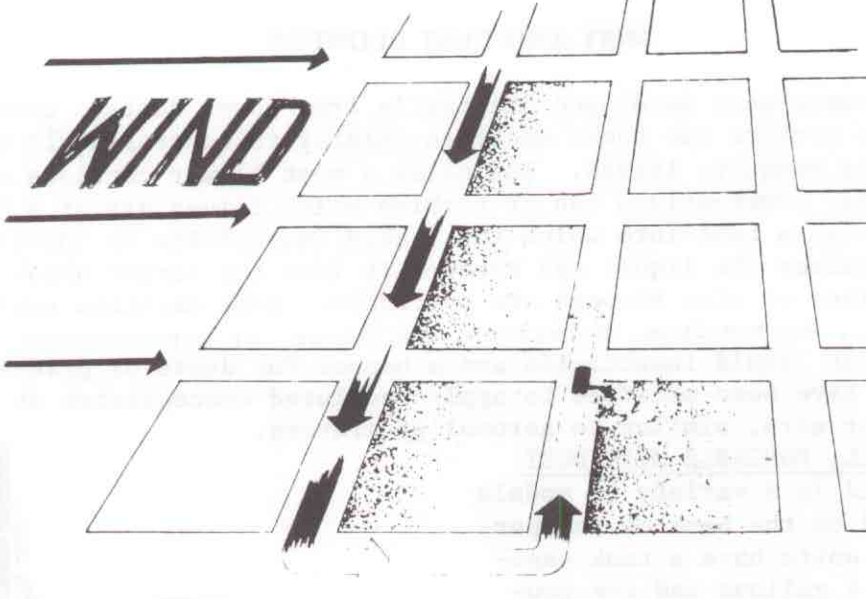
Mists are composed of droplets 50 to 100 microns in diameter (see page 38), particles of sufficient size to settle to the earth fairly rapidly, but remain suspended in the air for sufficient time to cover a 200 to 300 foot swath with only a light wind to promote distribution. This settling will occur despite the fact that there may be thermal air currents rising from the heated earth during the daytime.

Fogs are composed of much finer droplets, from 0.1 to 50 microns in diameter, that remain suspended for a long period of time, settling only in relatively still air. These particles are likely to rise in the daytime and produce little or no kill of insects during this period.

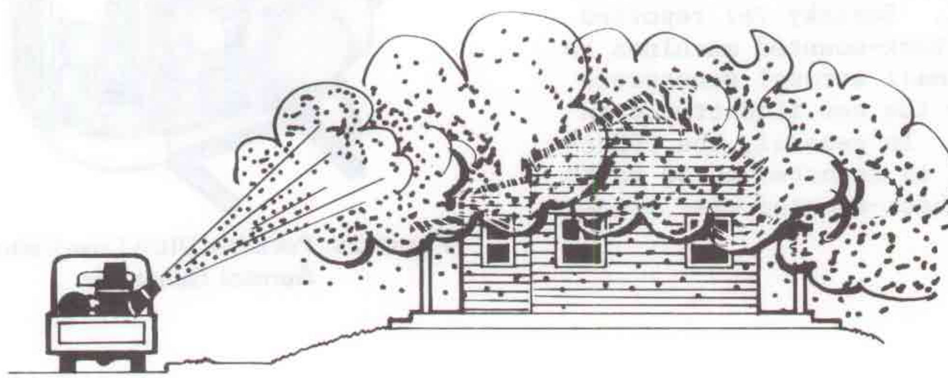
The above considerations indicate that the mist blowers are especially suitable for daytime operations such as fly control, and that fog applicators are most effective during the evening, night, and early morning hours, particularly for adult mosquito control.

Mists are usually dispersed at rates of 7 to 25 gallons per mile at a vehicle speed of 5 miles per hour. Fogs are applied at rates up to 80 gallons per hour dispersed from a vehicle moving at speeds up to 10 miles per hour, occasionally at much higher rates and greater speeds. Finished formulations contain from 0.5 to 8 ounces of technical grade insecticide per gallon in oil, or in the case of the nonthermal fog generator, in a water emulsion. The insecticide must be dispersed downwind, as a light breeze will facilitate treatment of an effective swath. The effective swath width is sometimes much wider in open swamps and open woodlands than in areas with dense vegetation which tends to filter out many of the droplets *(7)*.

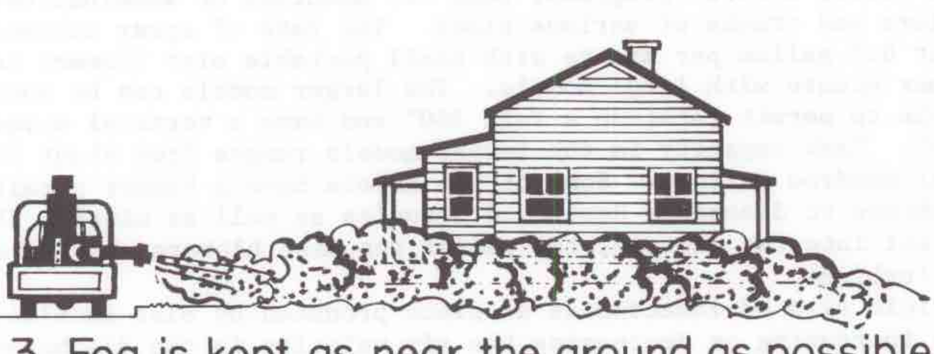
The chief advantages of mist and fog applicators are: (1) economy of operation due to their low manpower requirements, (2) ability to apply small amounts of concentrated material to a large area, and (3) large portions of a city may be treated in a short period of time during disasters and in periods of high insect abundance. The chief disadvantage in their use for treating urban areas is the fact that cars and windows may be spotted by the insecticide and shrubbery may be burned by the oil if machines are not properly operated. Most of these machines are simple in design and can be maintained in good condition with a reasonable amount of repairs and servicing.



1. Treat block by block.



2. Mist is directed over housetops.



3. Fog is kept as near the ground as possible.

Figure 28. Space Application of Insecticides

MIST AND DUST BLOWERS

Mist blowers were developed originally from power dusters used on crops. Public health workers use these machines chiefly to control adult mosquitoes and flies, and mosquito larvae. Basically a mist blower consists of a large capacity, power-driven fan or turbine which drives air at a high velocity through a tube into which the liquid insecticide is injected. The air blast atomizes the liquid and carries it into the target area. Many models and sizes of mist blowers are available. Some machines apply only liquids, i.e., suspensions, solutions, emulsions, or concentrates; others have a tank for liquid insecticide and a hopper for dusts or granules; while still others have been modified to apply undiluted concentrates at only a few ounces per acre, similar to aerosol generators.

THE SMALL, PORTABLE MIST/DUST BLOWER is sold in a variety of models to be carried on the back of an operator. These units have a tank capacity of 2 to 4 gallons and are powered by a small air-cooled gasoline engine. Some of these machines can disperse liquids, dusts, or granules. They are extremely useful in dispersing adulticides or larvicides over terrain where wheeled vehicles can not travel. Buzicky *(6)* reported modifying back-mounted machines to serve as small aerosol generators similar to the one illustrated in Figure 29. In general, the effective swath is reported as 30 to 80 feet with back-mounted mist blowers.

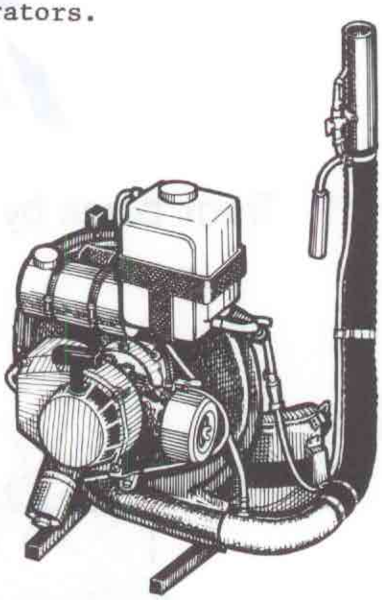


Figure 29. Portable Ultra-Low-Volume Aerosol Generator

THE LARGE MIST/DUST BLOWER (Figure 26) is manufactured in many forms for different insect control programs, some for mounting on wheelbarrows, others for trailers and trucks of various sizes. The rate of spray discharge varies from about 0.5 gallon per minute with small portable mist blowers to 50 gallons per minute with large models. The larger models can be mounted on a turntable to permit rotation a full 360° and have a vertical movement of 45° to 75°. Tank capacity in the larger models ranges from about 50 gallons to several hundred gallons. Some of the models have a hopper permitting these machines to discharge dusts and granules as well as mists. These blowers fall into two classes, the radial fan mist blowers and the axial flow air turbines.

Particle size of insecticide droplets produced by mist machines may be varied by increasing or decreasing the air velocity in the discharge nozzle, utilizing fine or coarse spray nozzles, or using light or heavy spray oils.

Truck- and boat-mounted mist blowers have been utilized for larviciding large mosquito breeding areas. The fine aperture nozzles produce a mist that will drift for as much as 1500 ft. in a light wind for treatment of water surfaces. Deposited on adjacent vegetation, the spray serves also as a residual treatment for adult mosquitoes entering or leaving the area. Frequent treatment of mosquito breeding sites will result in a build-up of deposits sufficient for residual control. To kill broadleaf plants and shrubs during the larvicidal application, the herbicide 2, 4-D in ester form may be added to the insecticide spray. Sprayers must be cleaned thoroughly after the use of weed killers if subsequent use will be made in urban areas where shrubs may be damaged. There are many mist applicators on the market that are worth considering for insect control programs. When used on small city programs, these machines often have a dual purpose since they are suited for use in protecting trees and large shrubs from insect pests, as well as for fly, black fly, and mosquito control.

Most modern insecticidal application units have a self-starter and remote controls for operating the equipment from inside the cab of the vehicle. This makes for convenient one-man operation. Other desirable accessory equipment includes low-speed speedometers, a recording tachygraph for recording hours of treatment, direction of vehicle operation, etc,; two-way radio so the operator can communicate with operational headquarters; fire extinguishers and first aid kit. Any vehicle operating at low speeds along highways or in urban areas should be equipped with an approved rotating amber beacon light, flags in stake holes, and large identifying organizational signs on the sides or back of the truck. Equipment dealers can offer good advice as to desirable accessories. Use of rotating warning lights on street vehicles may require the approval of the state motor vehicle unit and/or the local police department.

FOG GENERATORS

Fog generators are often preferred to mist applicators in urban mosquito control programs because of the smaller droplet size, typically in the range of 0.1 to 50 microns, with less problems of "burning" vegetation, or spotting of automobile finishes. The visible cloud of insecticide produced by these machines often has a beneficial psychological effect on the general public during outbreaks of mosquitoes, or during disease epidemics as encephalitis, i.e., the people believe the mosquito organization is working to control the problem. Conversely, the cloud of insecticidal fog produced by some thermal fog generators has created traffic problems and even led to the death of children running into, or bicycling into, the fog and being hit by oncoming automobiles. Fog applicators include mechanical fog generators, thermal fog generators, pulse-jet generators, and cold fog generators.

THE MECHANICAL FOG GENERATOR breaks up the insecticide into fine particles by mechanical means. The insecticide can be in either a water emulsion or an oil solution. The emulsion is sometimes preferred as less likely to cause "burning" of vegetation outside, or to have less fire or explosion hazard indoors, than atomized oil solutions. In one of the mechanical fog generators concave discs are mounted on a hollow drive shaft, with a cavity between each pair of discs. Turning at high speed, the discs expel both air and liquid outward between their rims by centrifugal force. The partial vacuum thus created pulls liquid from the tank through the hollow drive shaft and into the cavities by means of feeder holes in the shaft. A blower on the same shaft drives the insecticide droplets away from the machine at a high velocity. Small units utilizing an electric motor as the power source have been developed for use in buildings and in limited areas outdoors. From 1/2 to 2 ounces of liquid per 1000 cubic feet may be applied, depending on the valve setting and the operation time. Particle size depends upon the speed of rotation, the delivery rate, and the viscosity of the insecticide. There is evidence that these machines produce droplet sizes of remarkable uniformity *(5)*. Larger units are available that have many discs instead of the 2 discs on the smaller models. These machines, powered by a gasoline engine, are designed for use outdoors and discharge up to 5 gallons of insecticide in 4500 cubic feet of air per minute.

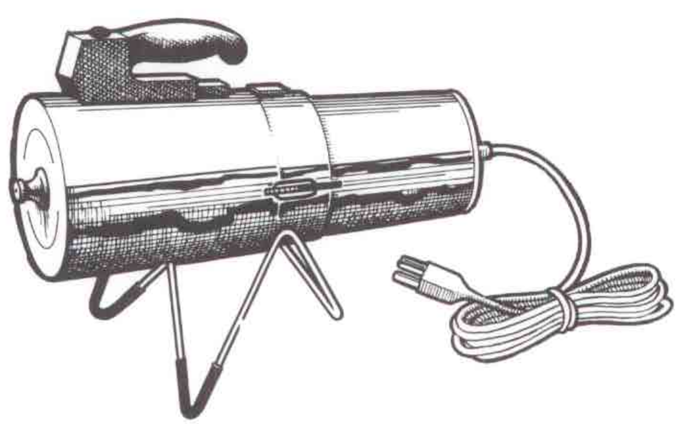


Figure 30. Electrical Mist Blower

THE "COLD FOGGER" is another type of mechanical aerosol generator. This machine utilizes a special nozzle permitting the use of a low-pressure, large-volume air source for atomizing the insecticide. A number of models have been developed by military, civilian, and commercial agencies. Many of these machines produce a swath of 300 feet or more. Some authorities believe that the "cold foggers" have three advantages over the thermal fog generators: (1) there is no visible cloud of insecticide to create traffic hazards, (2) there is no heat applied to cause thermal breakdown of insecticide, and (3) water emulsions can be used as effectively as diesel fuel oil solutions for the carrier, resulting in a saving in solvent costs. Studies by many workers indicate that fogs produced by this machine cause different mortalities in various species of mosquitoes and flies, but that, in general, the nonthermal generator was about as effective as the thermal fog machine when malathion, fenthion, and naled were used as the toxicant *(21)*.

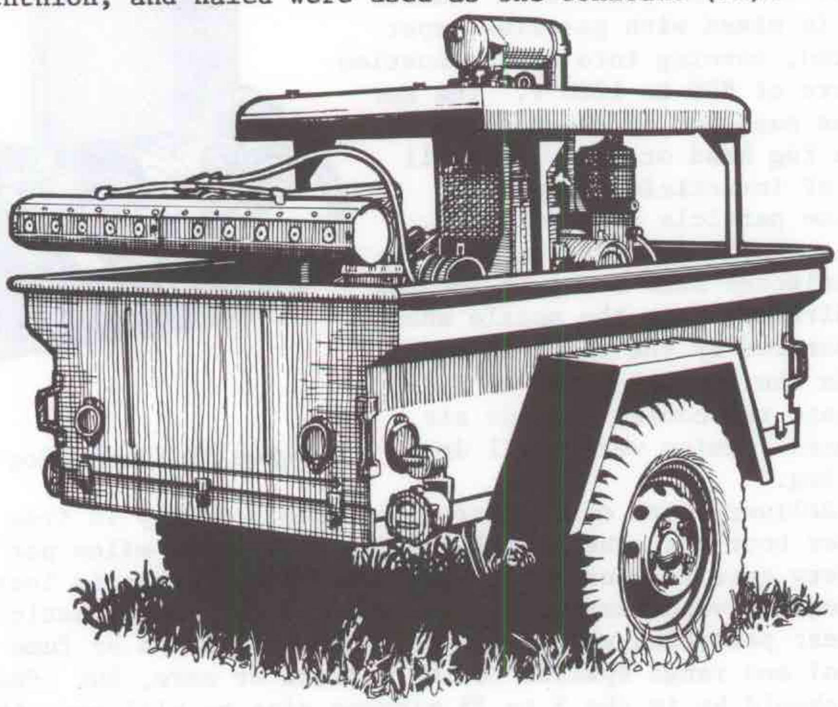


Figure 31. Cold Fogger

THE THERMAL FOG GENERATOR breaks up the insecticide into an aerosol by means of hot exhaust gases. These machines had their origin with the smoke machines which were used by the U.S. Navy to conceal ships from the enemy during World War II. Modern thermal fog generators have acquired their popular name of "fog" machines owing to the fog-like or smoky appearance of the mass of small droplets produced by these machines.

Soon after World War II many people designed a variety of "plumbers nightmares," with a maze of pipes for injecting insecticide into the hot exhaust of a power lawnmower, a portable gasoline engine, or a truck exhaust pipe. However, these machines produced fogs with a wide range of droplet sizes, did not always kill mosquitoes effectively, and produced greatly increased heat in the gasoline engines. They were gradually supplanted by commercial models developed specifically for insect control programs.

Hundreds of models of thermal fog generators are available commercially. The smaller, hand-carried machines weighing 25 to 50 pounds when fully loaded are used for making space treatments in limited outdoor areas such as drive-in theaters, parks, motels, and summer camps. Larger commercial machines may weigh a ton or more with insecticide tank and liquid gas tanks. They have capacities of 30 to 120 gallons per hour. For treatment of large outdoor areas, a unit having a minimum capacity of 40 gallons per hour is required for satisfactory operation and results. These larger units are operated continuously for 6 to 8 hours a night, several times a week, and therefore must be well-designed and ruggedly constructed to avoid excessive mechanical failures *(2)*.

The larger thermal fog generators use an air-cooled motor to run the air blower, the fuel pump, and the insecticide pump--the only moving parts of the equipment. Air is delivered by a rotary air blower into the combustion chamber where it is mixed with gasoline vapor and ignited, burning into the combustion temperature of 800 to 1200°F. The hot gases then pass out of the machine through a fog head or spud. The oil solution of insecticide is pumped through the particle size selector, which is a simple delivery valve, and then is injected into a cup in the fog head or directly into the nozzle where it is vaporized by the blast of hot gases. As the hot oil vapor is discharged into the cooler outside air, it condenses forming very small droplets or "fog."

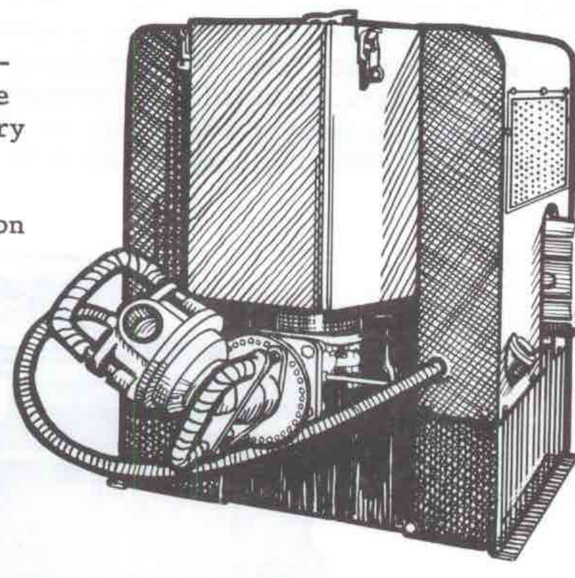


Figure 32. Thermal Fog Generator

The delivery rate of the large machines normally is from 40 to 120 gallons per hour with the vehicle moving at 5 to 10 miles per hour. As the delivery rate is increased, the burner temperature is increased to assure adequate vaporization of the larger volume of insecticide solution. The smallest particles may be in the range of a smoke or fume (0.001 to 0.1 micron) and range upwards to 100 microns or more, but ideally the majority should be in the 5 to 25 microns size to kill mosquitoes and flies. There is frequently a "sorting out" of particles with the larger ones closest to the machine and the smallest ones drifting several hundred feet or more with a favorable wind. This is a distinct advantage where few access roads are available and these wide swaths must be relied upon to kill insects several hundred feet away from the machine. Some authorities believe that there may be some decomposition of insecticide due to heat. This loss may be minimized by using less volatile oils. The use of high flash point oils will reduce possibility of explosion.

For most routine adulticiding, No. 2 fuel oil is the preferred solvent for insecticides. Oils of higher viscosity than No. 2 diesel oil, sometimes called "fog oils," generally produce a more spectacular fog than diesel oil but several comparative tests of these oils have shown they have no advantage over No. 2 fuel oil for killing adult mosquitoes. Since these special "fog oils" usually are higher priced, No. 2 diesel oil remains the solvent of choice for thermal fogging.

The organophosphorus insecticides frequently require special sludge inhibitors, such as Thiosperse with malathion. The manufacturer's directions should be followed when using the various insecticides.

THE PULSE-JET AEROSOL GENERATOR utilizes a pulse-jet engine similar to that used in the German V-1 buzz bomb during World War II. One machine has only three moving parts, requires no lubrication, has no rotating parts, and weighs less than 100 pounds. Gasoline is burned at the rate of sixty explosions per second, producing hot exhaust gases. An oil solution of insecticide is forced into the tank under 6 psi pressure tapped from the engine head, and the rate of flow is determined by the formulation valve. Particle size may be regulated by adjusting the flow of insecticide from 0 to 45 gallons per hour, the latter rate depending upon the viscosity of the insecticide liquid. In tests of a mixture of 1 part Diol and 5 parts of kerosene, dispersed at the rate of 45 gallons per hour, a mass median diameter of 22 microns was produced *(5)*. The technique of using the pulse-jet aerosol generator is similar to that used when operating other fog generators. The loud noise produced by the pulse-jet engine is objectionable during the night hours. However, one of the chief advantages of this machine is the fact that the flutter valves cost less than a dollar to replace. An electrical spark and an air pump are used to start it, but are not required after operation has commenced, as the machine is self-igniting after combustion has been initiated. Some small models may be carried by hand to treat areas inaccessible to vehicles.

Experience indicates that the particle size of an aerosol should not be less than 10 or more than 50 microns in diameter. Finer particles will rise from the treated area rapidly, and there is some evidence that insects may fly through such a fog without obtaining a lethal dose of insecticide. Most flies and mosquitoes will be found in a zone within 25 feet of the earth's surface and droplets within the 30 to 70 micron range tend to concentrate fog in this layer.

Many important factors must be taken into account in computing operating costs for space sprayers such as: (1) insecticide used and application rate; (2) type of machine used; (3) labor and supervision charges; and (4) type of area treated. Other items, such as insurance, mixing time and supervision should be considered when computing costs.

Technical grade materials are used in formulating most of the solutions as they are easily dissolved at low concentrations, and they are available for purchase. The solutions thus compete with emulsions economically. Oil solutions must be used in the thermal fog machines as emulsions do not produce a satisfactory fog.

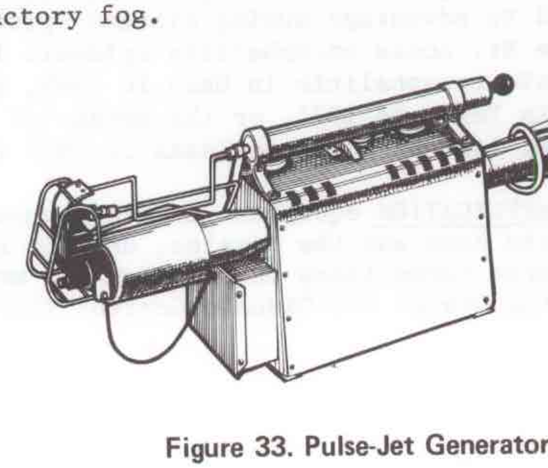


Figure 33. Pulse-Jet Generator

ULTRA-LOW-VOLUME APPLICATIONS

During the past several years there has been a rapid and dramatic increase in the use of undiluted insecticides applied at extremely low dosage to control insects of public health and agricultural importance.

Ultra-low-volume (ULV) spraying is defined as the application by aircraft or ground equipment of technical insecticide at a dosage rate not to exceed two quarts per acre. For mosquito control the dosage rate may be as low as 0.5 ounce per acre with naled or 3 ounces per acre with malathion.

In the ULV method of application, the technical insecticide is atomized into millions of tiny droplets, the majority varying from 5 to 50 microns (from 1/5000 to 1/500 of an inch) in diameter, and dispersed evenly over the treated area. This technique has resulted in substantial savings in money and time. For example, conventional aerial sprays to control mosquitoes in southern United States are applied at a rate of one to six quarts per acre (32 to 192 fluid ounces) depending on the insecticide and vegetation cover. As ULV sprays, naled and malathion are applied at rates from 0.5 to 3 fluid ounces per acre, or 1/64 the amount of spray previously applied. Thus, approximately 40 to 250 acres can be treated with a single gallon (128 ounces) of malathion or naled.

There are savings not only in the cost of reduced amounts of insecticide itself, but also in eliminating the diluent, the mixing, and the transportation of the larger volume of diluted spray.

For example, with malathion, a plane with a 500-gallon tank applying conventional sprays at a gallon per acre could treat 500 acres, whereas the same plane fitted with ULV equipment applying technical grade malathion at 3 ounces per acre (or about 40 acres per gallon) could treat (500 gallons x 40 acres/gal.) 20,000 acres. This difference represents a considerable saving in loading, in time for take-offs and landings, and in being able to stay in the air operating in early morning hours when the temperature is below 80°F. and the winds are below 10 miles per hour.

In most cases a wider swath of insecticide is obtained with technical material than with diluted formulations. Reduced volumes also mean that the size of dispensing equipment can usually be reduced. Thus, smaller and less expensive trucks or aircraft are required for transportation and application of insecticide.

This new capability of applying effective mosquito control over immense areas in a short time was used to advantage during disease epidemics and natural disasters, such as the St. Louis encephalitis epidemic in Dallas in 1966, the outbreak of California encephalitis in Ohio in 1969, the Venezuelan equine encephalitis epidemic in Texas in 1971, or the hordes of mosquitoes on millions of acres of flooded land in southern Texas in 1967 following hurricane Celia.

AERIAL ULTRA-LOW-VOLUME APPLICATION equipment consists essentially of three main parts: the pump, the boom and the nozzles, and the spray tank. The following discussion on these three items is based on the work of Kilpatrick and co-workers at the Center for Disease Control *(14)*.

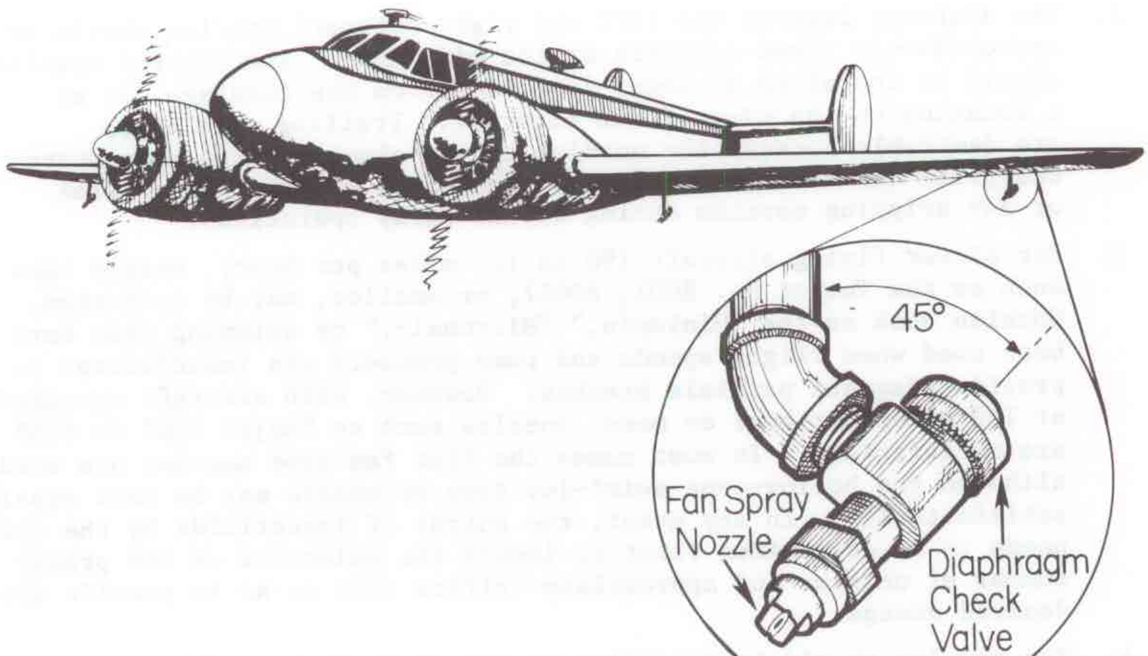


Figure 34. Airplane with Ultra-Low-Volume Aerosol Equipment

Pump

1. Positive displacement or centrifugal pumps should be used.
2. Electrically driven pumps are usually more dependable but pumps driven by gasoline engines may be used.
3. If a centrifugal pump is used, a bleed line of 3/16" to 1/4" diameter should be installed on the high point of the impeller chamber to release trapped air. No bleed line is required if pumps of the positive displacement type are used.
4. The pump selected should have a capability of producing at least 150 pounds per square inch with an output rate of 3 to 5 gallons per minute.

Boom and Nozzles

1. Preferably, the boom should be installed inside the wing. However, booms can be installed outside the wings if they are so designed that flight capabilities of the aircraft are not materially decreased.
2. The distance between the left and right outboard nozzles should be approximately three-quarters of the wing span. The inboard nozzles should be installed at least four feet from the fuselage, or at a location on the wing of the aircraft. Trailing edge booms are desirable because the nozzles can be placed on the boom where the pilot can readily see them to check any plugging of nozzles or any dripping nozzles during actual spray operations.
3. For slower flying aircraft (90 to 125 miles per hour), nozzle tips such as the Teejet No. 8001, 80067, or smaller, may be indicated. Nozzles such as the "Minispin," "Micronair," or spinning disc have been used when flight speeds and pump pressure are insufficient to provide adequate particle breakup. However, with aircraft operated at 150 miles per hour 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 used equally satisfactorily. In any event, the output of insecticide by the system needs to be determined first to insure the selection of the proper number of nozzles and appropriate orifice size so as to provide the desired dosage.
4. The nozzles should be installed on the aircraft at a 45° angle downward and facing forward into the airstream to ensure proper atomization.
5. Diaphragm check valves should be used on all nozzles to ensure positive cutoff of the spray. These should be set at 5 to 12 pounds per square inch and should be checked frequently and replaced as needed.

Spray Tanks

1. Spray tanks for holding technical grade insecticides should be made of aluminum, stainless steel, or fiberglass. Some workers who use naled for ULV aerial application prefer fiberglass. The tubing from the tank to the boom should be stainless steel or plastic if naled is used. Neoprene is satisfactory if malathion is the insecticide. All tubing should be able to withstand 2000 pounds per square inch pressure.

The following performance requirements for ULV aerial spraying are necessary for effective mosquito control *(7, 14)*:

1. The dosage rate should be about 3 fluid ounces of technical grade malathion; or 0.5 to 1 ounce of technical grade naled, per acre. Although other materials such as pyrethrins, resmethrin, Abate, chlorpyrifos, and fenthion have been used experimentally, as of September 1976, only malathion and naled are labeled for ULV applications, and then only by trained mosquito control personnel or pest control operators.

2. The optimum size of ULV droplets appears to be about 25 microns MMD (Mass Mean Diameter), ranging up to 50 microns MMD. 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).

3. The deposit should average at least 15 droplets per square inch, with 20 to 25 droplets per square inch preferable.

4. The spray should be applied from aircraft flying at a speed of about 150 miles per hour and at an altitude of 100 to 150 feet, producing swath widths of 300 to 700 feet. Greater swath widths have been used successfully with multi-engine aircraft flying at higher altitudes. However, droplet size and density per unit area lose uniformity with increased swath width because of the natural sorting of droplets and the small droplets falling more slowly and drifting further than the large droplets.

5. Treatments should be made only when wind currents are below 10 miles per hour.

6. Insecticide should be applied when temperatures are below 80°F. or before any temperature inversion occurs.

7. Single-engine aircraft may be used in rural or uncongested areas; multi-engine airplanes must be used over populated areas.

The calibration of ULV spray planes to produce correct droplet size 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. One of the most readily available sources of information about the ULV procedure, although it is primarily for ground ULV equipment, is the 8-page statement by the American Cyanamid Company, manufacturer of malathion, in the March 1971 issue of Mosquito News, pp. IV to XI *(1)*.

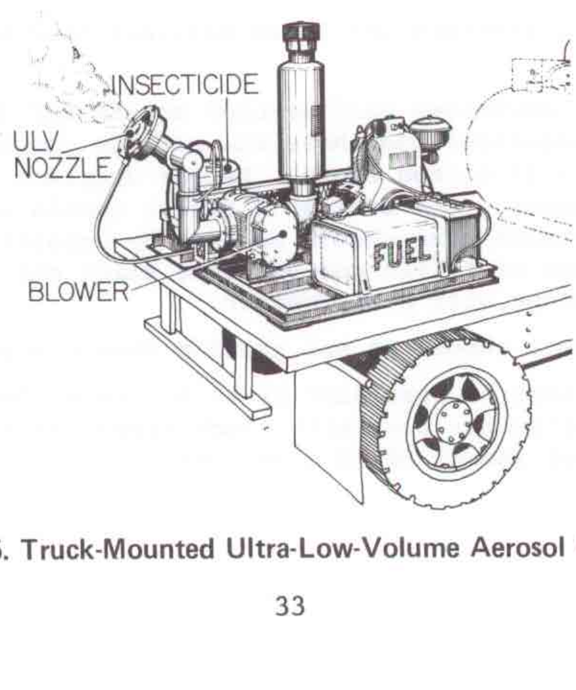


Figure 35. Truck-Mounted Ultra-Low-Volume Aerosol Generator

GROUND ULTRA-LOW-VOLUME APPLICATION of insecticides has been used to control insects of public health importance since the mid-1960's. This relatively new method may supplant or supplement the thermal fog, and cold fog and mist, applications that have been used since World War II. Mount *(22)* reported that ULV cold aerosols were more effective against adult mosquitoes than thermal aerosols. ULV applications frequently use less insecticide per acre treated than do cold or thermal foggers or misters, resulting in savings in insecticide cost, elimination of diluents, and time for loading or travel of equipment. Other advantages of ULV aerosols are that they do not produce dense fogs--as do thermal fogs--that constitute a traffic hazard and might result in deaths of children running or bicycling into the fog. The ground ULV aerosol machine is relatively small; its insecticide tank is usually of the 5- to 10-gallon size; and it is usually mounted on a small vehicle such as a 1/2 ton pickup truck. By contrast, the thermal fog, cold fogger, or ground mister machine is much larger and heavier; its insecticide tank may contain 25 to 200 gallons or more; and it is usually mounted on a larger vehicle, such as a 1- to 3-ton truck. Lofgren *(17)* has critically reviewed and summarized the literature concerning the ULV application of insecticides.

On the other hand ULV applications are "somewhat less effective than thermal fogs in heavy vegetation" *(7)*. In some areas, car spotting, or damage to automobile finishes, has occurred because of the corrosive properties of some of the insecticides, but generally only when large droplets (greater than 100 microns, the diameter of a human hair) are present in the spray. Greater care must be taken in handling the concentrated or technical insecticides used in the ULV method because of increased degree of exposure to toxic concentrations of the chemical, particularly by spillage during loading operations, than with the diluted fuel oil formulations used in the thermal foggers, cold foggers or misters.

A number of ULV ground applicators such as the Leco, Curtis, Micro-Gen, Root-Lowell, Douglas, Micro-Mist, and Whitmire are sold commercially. For indoor application, synergized pyrethrins are labeled for use in ULV insecticide application. Malathion, naled (Dibrom), fenthion (Baytex), resmethrin (SBP-1382), chlorpyrifos (Dursban) and synergized pyrethrins are labeled for outdoor use.

Performance requirements for these machines have been published *(1, 7)* as follows:

1. The Ultra-Low-Volume cold aerosol nozzle for dispersal of malathion to control adult mosquitoes must have the minimum capability of producing droplets in the 5 to 27 micron range. Larger droplets may permanently damage automobile paint. The average diameter should not exceed 12 microns. Determination of droplet size should be made by depositing a sample of the aerosol on a silicone or teflon coated glass slide and measuring the droplets under a microscope with a micrometer.

2. Tank pressure should be not greater than 6 pounds per square inch.

3. Flow rate must be regulated by an accurate flow meter, and not greater than one gallon per hour with truck speeds of 5 miles per hour, or 2 gallons at truck speeds of 10 miles per hour.

4. The nozzle should be in the rear of the truck and pointed upward at an angle of 45° or more.

5. Vehicle speed should not be greater than 10 miles per hour. The ULV machine should be shut off when the vehicle is stopped.

INDOOR APPLICATION OF ULTRA-LOW-VOLUME AEROSOLS. The use of ultra-low-volume aerosol equipment to control insect pests indoors has been increasing rapidly in recent years. Shinkle *(29)* has summarized the advantage of the aerosol type of application as follows: increased speed of application, decreased cost of application, reduced environmental contamination, reduced quantity of pesticides required, increased penetration of concealed areas, ease of calibration of equipment, no thermal degradation of insecticide, reduced fire hazard, and better control of particle size. Shinkle discusses the use of the ULV method in food warehouses and elevators, canneries, bakeries, breweries and meat plants. There are many types of aerosol generators now available commercially. One of these is shown in Figure 36.

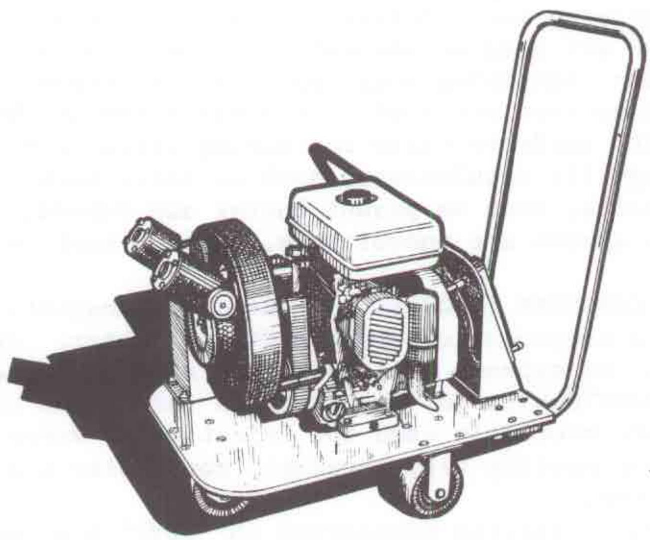


Figure 36. Ultra-Low-Volume Aerosol Generator for Indoor Use

OTHER APPLICATION EQUIPMENT

POURING of chemicals may be of value under certain conditions. Measured amounts of insecticide may be poured into fast-flowing streams for blackfly control. A sprinkler can is useful for mosquito larviciding of 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. Do not pollute human water supplies.

DRIP CANS are superior to pouring or dragging for water treatment because insecticide dosage can be controlled more exactly. They are better suited to use in moving 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.

POISON BAITS are used occasionally by public health workers. Chicken watering fountains containing sugar water and an organic phosphorus compound such as dichlorvos are used to control flies in chicken houses. Shallow trays covered with hardware cloth containing granular fly baits may be placed in areas with high fly populations, such as dairy barns. Small containers with cockroach baits, such as peanut butter and Kepone, may also be placed in situations where sprays are undesirable, such as book cases, filing cabinets, and desks.

GELATINOUS CAPSULES ("TOSSITS") containing mosquito larvicide are useful for immediate treatment of small bodies of water. Inspectors can easily use them, saving the expense of sending out a control crew.

PRESSURE INJECTORS to put insecticides into water have been little used, (although they are routinely used for injection of water treatment chemicals), but are useful for putting very carefully controlled quantities of insecticide into the water.

RESIN STRIPS containing dichlorvos (or DDVP) are used to control insects in buildings, such as cockroaches under sinks, or silverfish, clothes moths, and carpet beetles in closets. These strips are used at a rate of one strip per 1000 cubic feet. They are also used to control mosquito larvae in catch basins *(7)*. They are effective for 3 to 4 months.

FLY CORDS are made commercially by dripping cotton cord in organic phosphorus insecticides such as parathion, diazinon, or ronnel. When installed in dairy barns, loading docks, and similar situations at a rate of 30 linear feet per 100 square feet of floor space, fly cords often provide effective fly control for 3 months or longer.

THE RELATIONSHIP BETWEEN INSECTICIDAL APPLICATION AND PARTICLE SIZE

The effectiveness of an insecticide is greatly influenced by the size of the droplets or particles into which it is broken when applied. For example, in residual applications a spray is desirable in order to wet the surface and leave a long-lasting deposit, while in space spraying to kill mosquitoes and flies on the wing a mist or fog should be used so that the insecticide will remain suspended in the air for a time to kill the insects exposed to the droplets.

Insecticides may be applied either as liquid or as dusts.

Liquid sprays range from rain-like drops delivered by orchard sprayers to mists and fogs produced by mist, fog, or aerosol generators. The following discussion is based on that of Dr. A.W.A. Brown [in *(2)*]. It is impossible to break up a liquid into entirely uniform droplets, although the range of droplet size may be considerably restricted. There are always some fine droplets among the others, even when the spray is rather coarse. The usual practice is to refer to the mass median diameter (MMD) of the spray which is the droplet diameter which divides the volume or mass of the spray into two equal portions, respectively, more finely and more coarsely atomized. 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.

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 may be defined as assemblages of solid particles or liquid droplets suspended in air and ranging in size from 0.1 to 50 microns. Insecticidal aerosols and fogs may be produced by spraying insecticides into a blast of hot air as with the thermal aerosol generator, or by mixing them with a liquified gas which is then released through small orifices, as with the household "bug bomb." They can also be produced by atomization from very fine nozzles, or by being thrown off the rim of high-speed rotors.

Smokes and fumes consist of particles in the range of 0.1 to 0.001 microns in diameter. They are common in the output of thermal fog generators employing the exhaust of an internal combustion engine and are caused by the almost complete vaporization of the oil or by the partial combustion of the insecticidal formulation.

Vapors consist of airborne insecticide in the droplet-size less than 0.001 micron. Lindane may be vaporized by heat, and dichlorvos (DDVP) vapo are given off for many months by DDVP resin strips.

Insecticidal dusts occur in three sizes:

Coarse dusts have a particle size about 175 microns or larger

Medium dusts range from 45 to 175 microns.

Fine dusts have a particle size of 44 microns or less.

Fine dust particles will pass through a 325 mesh screen, i.e. one with 325 wires to the inch. A coarse dust is used where excessive drift must be avoided, as in airplane application.

The classification of the different types of dispersed insecticides according to size range in microns is therefore as shown in Table 4 below.

TABLE 4. CLASSIFICATION OF DIFFERENT TYPES OF DISPERSE INSECTICIDES

[Adapted from Brown (2), and Glasgow (12)]

Type	Size in Microns
Rain	4000 and larger
Coarse Spray	400 and larger
Fine Spray	100 to 400
Mist	50 to 100
Aerosols and fogs	0.1 to 50.0
Fumes and smokes	0.001 to 0.1
Vapors	Less than 0.001
Coarse dust	175 and larger
Medium dust	45 to 175
Fine dust	44 or less

A micron is 1/1000 of a millimeter, or about 1/25,000 of an inch.

During the past few years increasing concern has been expressed about the effects of insecticides on non-target organisms, particularly from the build-up of insecticides in the environment following repeated applications. Therefore, there has been great interest in recent research indicating that very effective control of insects could be obtained by dispensing very small amounts of insecticide (such as 0.5 ounce of naled or 3 ounces of malathion per acre) in the form of millions of tiny droplets evenly dispersed over large areas, i.e. by the ultra-low-volume techniques.

Brown (2) has reported that the effectiveness of an insecticide increases with an increase of its exposed surface. For droplets of different diameters, the volumes are to each other as the cubes of the diameters, while the surfaces are to each other as the squares of the diameters. Thus, for equal volumes of one aerosol dispersed as droplets of 50 microns in diameter and another as droplets of 5 microns in diameter, there would be 10 x 10 x 10, or 1000 times, as many of the smaller droplets, while the surface area of the smaller droplets would be 10 x 10, or 100 times, as great as the total surface area of the larger droplets. He has applied these calculations to the number of droplets, their size, and the total surface covered when a liquid is dispersed as rain, a spray, or as a coarse, medium, or fine aerosol. In these 5 categories, one gram of water (approximately 1/30 of an ounce, or a little less than 1/4 of a teaspoonful) would have the number of droplets with the diameter and total surface area as described below:

Rain--about 30 drops, each 4 millimeters, or 4000 microns in diameter, and the total surface area of about 15 square centimeters, or an area equal to that occupied by three ordinary-sized postage stamps.

Fine mist or spray--30,000 droplets, each 0.4 millimeter, or 400 microns, in diameter, with a total surface area of 1500 square centimeters, or approximately 12 by 20 inches.

Coarse fog or aerosol--30,000,000 droplets, each 0.04 millimeter, or 40 microns in diameter, with a total surface area of 150,000 square centimeters, or approximately 10 by 14 feet.

Medium fog or aerosol--30,000,000,000 droplets each 0.004 millimeter, or 4 microns in diameter, with a total surface area of 15,000,000 square centimeters, or an area about equal to the combined area of two average-sized city lots, each 60 by 120 feet.

Fine fog or aerosol--30,000,000,000,000 droplets, each 0.0004 millimeter, or 0.4 micron in diameter, with a total surface area of 1,500,000,000 square centimeters, or about 37 acres.

These data are summarized in Table 5 as follows:

TABLE 5. RELATION OF NUMBER OF DROPLETS, DIAMETER OF DROPLETS, AND TOTAL SURFACE AREA COVERED BY FIVE TYPES OF LIQUID DISPERSIONS.
[From Brown, in (2)]

Type of Dispersion	Number of Droplets in one gram of water	Diameter of Droplets mm.	microns	Total Surface Area of Droplets (square cm.)
Rain	30	4.0	4000.0	15 (3 postage stamps)
Spray	30,000	0.4	400.0	1,500 (12 by 20 inches)
Coarse aerosol	30,000,000	0.04	40.0	150,000 (10 by 14 feet)
Medium aerosol	30,000,000,000	0.004	4.0	15,000,000 (2 city lots)
Fine aerosol	30,000,000,000,000	0.0004	0.4	1,500,000,000 (37 acres)

Another important aspect of particle size is associated with the time droplets of various sizes fall and the distance that they are carried downwind. Neither standard mechanical spray outfits delivering mist droplets with average diameters of 100 microns or less, nor thermal fog generators, drive the mist or fog any great distance from the nozzle. Indoors, convection currents and associated eddy currents rapidly carry a fine aerosol fog throughout all parts of an enclosed space. Outdoors, however, aerosol fogs depend for much of their unique effectiveness on horizontal transportation by wind. A 4-mile-per-hour wind, or gentle breeze will carry droplets of different diameters enormously different distances downwind from an elevation of 4 feet (the average height of the nozzle of a fog generator nozzle) until they settle to the ground. The data in Table 6 show these differences.

TABLE 6. RATE OF FALL IN STILL AIR, AND DRIFT ON A 4 MILE-PER-HOUR WIND, OF DROPLETS OF DIFFERENT DIAMETERS [Adapted From Brown, in (2)]

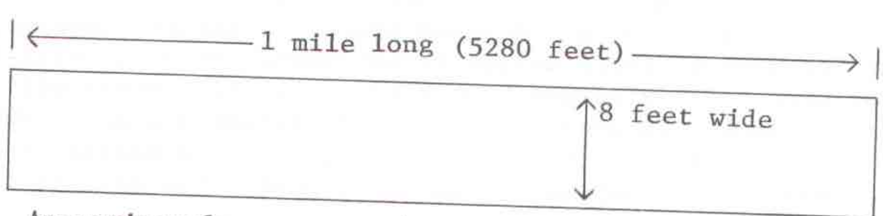
Droplet Size in Microns	Type of Dispersion	Rate of Fall	Time to Fall 1 Foot	Distance Carried Downwind
400.0	Coarse Spray	1.6 m/sec.	0.75 secs.	4.5 feet
200.0	Medium Spray	71.5 cm/sec.	1.70 secs.	10.10 feet
100.0	Fine Spray	30.0 cm/sec.	4.40 secs.	23.50 feet
50.0	Mist	7.6 cm/sec.	16.00 secs.	95.00 feet
20.0	Fog	1.3 cm/sec.	1.50 mins.	538.00 feet
10.0	Fog	3.0 mm/sec.	6.60 mins.	0.44 miles
1.0	Fog	30.0 microns/sec.	2.75 hours	44.00 miles
0.1	Fume	0.3 microns/sec.	11.50 days	4404.00 miles

Outdoor application of insecticides is frequently made on a pounds per acre basis. In calculating this dosage in the field, the speed of the vehicle can be noted, the swath width from the nozzle of the insecticide applicator can be measured, and the number of acres covered per hour determined by referring to Table 7.

TABLE 7. COVERAGE RATES FOR INSECTICIDAL APPLICATIONS

Rate of Travel (Miles per hour)	Number of Acres Covered per hour for Swath Widths of 50 feet	100 feet	200 feet	300 feet	400 feet
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 actual practice many field men figure that an acre is approximately one mile (5280 feet) long and 8 feet wide, or 42,240 square feet, as compared with the 43,560 square feet in an acre.



Approximately one acre (5280 x 8 = 42,240 square feet)

The acreage treated may be computed for field use by means of Formula 1

<u>Formula 1</u> Computation of Acreage Treated

$$\text{Number of Acres Treated} = \frac{\text{Miles covered x Swath Width (in feet)}}{8}$$

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

$$X = \frac{1 \text{ x } 200}{8} = 25 \text{ acres.}$$

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

<u>Formula 2</u> Computation of Insecticide Dosage of Liquid Formulations (Lbs./Gal.)

$$\text{Dosage Rate} = \frac{\text{Gallons applied x Insecticide in lbs./gallon}}{\text{Acreage Treated}}$$

Example 2 What is the dosage rate of malathion per acre when an area 5 miles long and 300 feet wide is treated with 40 gallons of malathion containing 0.4 lb. malathion per gallon of fuel oil solution? This is a standard operating procedure, the fog or mist applicator traveling at a rate of 5 miles per hour, dispersing 40 gallons of insecticide per hour.

Using Formula 1 the acreage treated is calculated as $\frac{5 \text{ x } 300}{8}$ = 187.5 acres.

Using Formula 2 the dosage rate = $\frac{\text{40 gals. x 0.4 lb/gal}}{\text{187.5 acres}}$ = 0.085 lb./acre.

The strength of the insecticide formulation is often expressed as the percentage of active ingredient rather than in pounds per gallon. Formula 3 may be used for computing dosage rate.

<u>Formula 3</u> Computing Dosage of Liquid Formulations (Various percentages)

$$\text{Dosage Rate} = \frac{\text{Gallons applied x weight/gal. of formulation x \% concentration}}{\text{Acreage Treated}}$$

Example 3 What is the dosage rate of malathion per acre when an area 5 miles long and 300 feet wide is treated with 40 gallons of 6% malathion?

Using Formula 1 the acreage treated is $\frac{5 \text{ x } 300}{8}$ = 187.5 acres

Using Formula 3 the dosage rate is $\frac{40 \text{ x } 7.1 \text{ x } 6\%}{187.5}$ = 0.09 lb/acre

When dusts or granules are used, the dosage may be computed by the following Formula 4.

Formula 4 Computation of Dosage for Dusts and Pelletized Insecticides

$$\text{Dosage Rate} = \frac{\text{Pounds applied x \% of concentration}}{\text{Acreage Treated}}$$

Example 4 What is the dosage rate when an area 1 mile long with an effective swath width of 200 feet is treated with 5% carbaryl dust at a rate of 20 pounds per mile.

Using Formula 1 the acreage is computed as $\frac{1 \times 200}{8} = 25$ acres.

Using Formula 4 the dosage rate is computed as $\frac{20 \times 0.05}{25} = \frac{1}{25} = 0.04$ lbs/acre

Insecticide applications are usually based on the dosage rate per acre, such as 3 ounces of malathion per acre. In calibrating equipment for aerial application, jars are placed beneath each nozzle and the pump pressure is regulated until the required number of ounces are emitted in a one minute interval. Using Table 8, a spray plane flying at 150 miles per hour with a 300 foot swath width, would cover 90 acres per minute when the four nozzles produce a total of 270 ounces per minute, or a single nozzle produced 67.5 ounces per minute. The spray width may be calculated in the field using red dye cards placed in a line across the flight pattern. Particle size of the droplets may be determined by the use of glass slides coated with silicone (General Electric SC-87 Dri-Film) which are later measured using a compound microscope with a mechanical stage and an eyepiece micrometer *(1)*.

TABLE 8

CALIBRATION OF AIRCRAFT FOR 3 LIQUID OUNCES* OF INSECTICIDE PER ACRE

Speed of Aircraft	Swath Width	Acres/min. Covered	Ounces/min. 4 nozzles	Ounces/min. 1 nozzle	Ml./min. 1 nozzle
90 mph	75'	13.5	40.5	10.13	300.5
	100'	18	54	13.6	402.6
	150'	27	81	20.25	601.0
	200'	36	108	27.0	799.0
	300'	54	162	40.5	1198.8
100 mph	75'	15	45	11.25	333
	100'	20	60	15.0	444.0
	150'	30	90	22.5	666.0
	200'	40	120	30.0	888.0
	300'	60	180	45.0	1332.0
110 mph	75'	16.5	49.5	12.5	368.5
	100'	22	66	16.5	488.4
	150'	33	99	24.9	737.0
	200'	44	132	33.0	976.8
	300'	66	198	49.5	1465.2
120 mph	100'	24	72	18.0	532.8
	150'	36	108	27.0	799.2
	200'	48	144	36.0	1065.6
	300'	72	216	54.0	1598.4
130 mph	100'	26	78	19.5	577.2
	150'	39	117	29.25	865.8
	200'	52	156	39.0	1154.4
	300'	78	234	58.5	1731.6
140 mph	100'	28	84	21.0	621.6
	150'	42	126	31.5	932.4
	200'	56	168	42.0	1243.2
	300'	84	252	63.0	1864.8
150 mph	300'	90	270	67.5	1998.0
	500'	150	450**	112.5	3330.0
	700'	210	630**	157.5	4552.0

* One liquid ounce = 29.6 ml.

** Eight or more nozzles usually required.

CARE AND MAINTENANCE OF INSECTICIDAL EQUIPMENT

Manufacturers of insecticidal equipment usually provide information on the care and maintenance of each type of applicator. Follow these instructions for lubrication, operation, and maintenance.

All applicator equipment requires diligent care if it is to be kept operating properly. Many complaints about equipment malfunction are traceable to improper maintenance.

HAND DUSTERS should be handled carefully; stored in a clean, dry place; lubricated as recommended by the manufacturer; and promptly repaired when damaged.

HAND SPRAYERS are generally a greater maintenance problem than dusters. Several basic rules should be followed in the care of a sprayer:

1. Handle it carefully.
2. Keep it clean.
3. Strain formulations through cheesecloth to keep particles out of it.
4. Rinse it out thoroughly after every use.
5. Every evening after use rinse it and then pump 1/3 gallon of clean water through it.
6. Do not let water freeze in it.
7. Every 3 months:
    a. Disassemble it completely.
    b. Put small metal parts into kerosene, allow to set, then clean with a small bottle brush.
    c. Soak nozzles, wands, and tank with trisodium phosphate solution, then clean with a scrubbing brush, then rinse thoroughly.
    d. Replace worn gaskets, broken parts, etc.
    e. Reassemble it.
    f. Pump 2 changes of water (with 1 cup of vinegar per gallon of water) through it.
    g. Pump clean water through it.
8. Oil certain parts, as in the spray gun.

POWER EQUIPMENT should be covered when not in use. Drain 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. Allow only experienced personnel to operate power equipment.

AUDIOVISUAL AIDS

The following films are available on free, short-term loan from:

National Medical Audiovisual Center (Annex)
Station K
Atlanta, Georgia 30333

Films should be requested at least 2 weeks before the preferred showing dates; if possible, two alternate showing dates should be given.

PERSPECTIVE ON PESTICIDES--M 1484. Motion picture, 16 mm., color, sound, 15 minutes, 1968. Cleared for television. Stresses the importance of proper use and storage of pesticides. Through various visual enactments, points out the dangers of storage in places easily accessible to children; storage in containers designed for other uses; and improper disposal of pesticide containers.

EPIDEMIOLOGY OF PESTICIDE POISONINGS--M 1668. Motion picture, 16mm., color, sound, 16 minutes, 1969. Cleared for television. Discusses epidemiology as related to pesticide poisonings. The various factors contributing to the occurrence of pesticide poisoning are described step by step and further dramatized by the portrayal of two actual cases of poisoning by pesticides.

ORGANOPHOSPHATE PESTICIDE POISONING--M 1747. Motion picture, 16 mm., color, sound, 19 minutes, 1969. Cleared for television. Describes for medical and para-medical audiences the symptoms of an organophosphate poisoning. The film includes a discussion of laboratory methods available for diagnosis and describes appropriate treatment for poisoned patients.

The following film is available free to governmental agencies from:

Department of the Air Force
Headquarters Aerospace Audiovisual Service (MAC)
Norton Air Force Base, California 92409

INSECTICIDES - FORMS AND SAFETY. Air Force TF 1-8208. Motion picture, 16 mm., color, sound, 19 minutes, 1963. Emphasizes the wide use of insecticides and describes various types, points out their differences and illustrates proper methods of application. Stresses importance of safety precautions in storing, mixing, and applying insecticides.

SELECTED REFERENCES

The literature on insecticidal equipment is enormous, much of it in the form of catalogues and brochures by equipment manufacturers. The Equipment Issue of "Pest Control" magazine--usually the May issue in recent years--has much information, illustrations, and a directory with addresses of manufacturers and distributors. The annual publication "Farm Chemicals," and the quarterly issues of "Mosquito News," have up-to-date information.

1. American Cyanamid Company. 1971. Mosquito control with ultra-low-volume ground equipment. Mosquito News 31 (1): III-XI.

2. American Mosquito Control Association. 1968. Ground Equipment and Insecticides for Mosquito Control. Amer. Mosq. Control. Assoc. Bull. 2, Rev. Ed. 101 pp.

3. Anonymous. 1970. Aerial spraying combats mosquitoborne epidemic. Public Works 66-67.

4. Boys, F. and F. Murphey. 1972. Pocket pesticide calibration guide. Dept. of Ent. and Applied Ecology, Univ. of Delaware, Newark, Del. 41 pp.

5. Brown, A.W.A. 1951. Insect Control by Chemicals. John Wiley and Sons, New York, New York 817 pp.

6. Buzicky, A.W. 1967. How we modified a back-pack sprayer for ULV insecticide applications. Pest Control 35 (6): 42, 44, 46.

7. Center for Disease Control. 1973. Public health pesticides. Pest Control 41 (4): 17-50.

8. Department of the Navy. 1971. Military Entomology Operational Handbook. Navfac MO-310. 315 pp.

9. Farm Chemicals Handbook. 1973. Farm Chemicals Handbook. Meister Pub. Co., Willoughby, Ohio 418 pp.

10. Fowler, D.L. and J.N. Mahan. 1973. The Pesticide Review, 1972. U.S.D.A. Agric. Stabilization and Conservation Service, Washington, D.C. 58 pp.

11. Frear, D.E.H. 1972. Pesticide Handbook-Entoma. 24th ed. College Science Pub., State College, Pa. 280 pp.

12. Glasgow, P.D. 1947. The significance of particle size in sprays and in aerosol fogs. Mosquito News 7 (1): 22-29.

13. Irons, F. 1967. Hand sprayers and dusters. USDA Home and Garden Bull. No. 63, 12 pp.

14. Kilpatrick, J.W. 1967. Performance specifications for ultra-low-volume aerial application of insecticides for mosquito control. Pest Control 35 (5): 80, 82, 84.

15. Kilpatrick, J.W., D.A. Eliason, and M.F. Babbitt. 1970. Studies of the potential effectiveness of ultra-low-volume aerial applications of insecticides against *Aedes aegypti* (L.) larvae. Mosquito News 30 (2): 250-258

16. Kilpatrick, J.W., R.J. Tonn, and S. Jatanasen. 1970. Evaluation of ultra-low-volume insecticide dispensing systems for use in single-engined aircraft and their effectiveness against Aedes aegypti populations in south-east Asia. Bull. Wld. Hlth. Org. 42: 1-14.

17. Lofgren, C.W. 1970. Ultra-low-volume applications of concentrated insecticides in medical and veterinary entomology. Ann. Rev. Ent. 15: 321-342.

18. Lofgren, C.W., H.R. Ford, R.J. Tonn, and S. Jatanasen. 1970. Control of Aedes aegypti (L.), the vector of dengue hemorrhagic fever in Asia, with ULV malathion applied from C-47 aircraft. Bull. Wld. Hlth. Org. 42 (2): 15-25.

19. Lofgren, C.S., H.R. Ford, R.J. Tonn, and S. Jatanasen. 1970. Equipping a multi-engined aircraft with a fuselage-mounted spray system for the ultra-low-volume application of malathion. Bull. Wld. Hlth. Org. 42: 157-163.

20. Morrill, A.W., Jr., R.G. Hahl, and K.A. Lotze. 1959. Studies on insecticidal fog generation for military use. Mosquito News 15 (2): 85-90.

21. Mount, G.A., C.S. Lofgren, J.B. Gahan, and N.W. Pierce. 1966. Comparisons of thermal and nonthermal aerosols of malathion, fenthion, and naled for control of stable flies and salt-marsh mosquitoes. Mosquito News 26 (2): 132-138.

22. Mount, G.A. 1970. Optimum droplet size for adult mosquito control with space sprays or aerosols of insecticides. Mosquito News 30 (1): 70-75.

23. Pampana, E. 1963. A Textbook of Malaria Eradication. Oxford Univ. Press, New York, N.Y., 508 pp.

24. Pant, C.P., G.A. Mount, S. Jatanasen, and H.L. Mathis. 1971. Ultra-low-volume ground aerosols of technical malathion for the control of Aedes aegypti (L.) Bull. Wld. Hlth. Org. 45: 805-817.

25. Potts, S.F. 1958. Concentrated Spray Equipment, Mixtures and Application Methods. Dorland Books, Caldwell, N.J. 398 pp.

26. Pratt, H.D. and K.S. Littig. 1961. Lice of Public Health Importance and Their Control. PHS Pub. 772, part 8: 16 pp.

27. Russell, P.F., L.S. West, R.D. Manwell, and G. MacDonald. 1963. Practical Malariology. Oxford Univ. Press, New York, N.Y. 750 pp.

28. Scott, H.G. and K.S. Littig. 1960. Insecticidal Equipment for the Control of Insects of Public Health Importance. PHS Pub. 774 32 pp.

29. Shinkle, M. 1973. Refinements of ULV--third generation technology. Pest Control 41 (8): 28-49.

30. Truman, L.C. and W.L. Butts. 1967. Scientific Guide to Pest Control Operations. Pest Control Magazine. Cleveland, Ohio. 187 pp.

31. U.S. Dept. of Agriculture. 1955. Insecticides and Repellents for the Control of Insects of Medical Importance to the Armed Forces. U.S.D.A. Circ. 977, 91 pp.

32. U.S. Dept. of Agriculture. 1966. Power Sprayers and Dusters. U.S.D.A. Farmers Bull. 2223, 18 pp.

33. World Health Organization. 1964. Equipment for Vector Control. Wld. Hlth. Org., Geneva, Switzerland, 200 pp.

34. World Health Organization. 1971. Application and Dispersal of Pesticides. Wld. Hlth. Org. Tech. Rept. Ser. No. 465, 66 pp.

35. Yeomans, A.H. and E.E. Rogers. 1951. Impinging aerosol particles on a microscope slide. U.S.D.A., Div. Control Insects, BEPQ, Special Report IN 2-25, 4 pp.

☆U.S. Government Printing Office: 1988—533-188