AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

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Batch 67

1. SUBJECT CLASSIFICATION	A. PRIMARY TEMPORARY
	B. SECONDARY

2. TITLE AND SUBTITLE
Insecticidal equipment for the control of insects of public health importance

3. AUTHOR(S)
Scott,H.G.; Littig,K.S.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1960	33p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
HEW/PHS

8. SUPPLEMENTARY NOTES (*Sponsoring Organization, Publishers, Availability*)
(In Training guide-insect control series)

9. ABSTRACT
(HEALTH R&D)

10. CONTROL NUMBER	11. PRICE OF DOCUMENT
PN-AAE-200	
12. DESCRIPTORS Equipment Insect control Insecticides	13. PROJECT NUMBER 14. CONTRACT NUMBER PASA RA(HA)-7-00 Res. 15. TYPE OF DOCUMENT

AID 590-1 (4-74)

INSECTICIDAL EQUIPMENT FOR THE CONTROL OF INSECTS OF PUBLIC HEALTH IMPORTANCE

TRAINING GUIDE - INSECT CONTROL SERIES

Harold George Scott and Kent S. Littig

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE, Bureau of State Services
Communicable Disease Center
Atlanta, Georgia
1960

Public Health Service Publication No. 774

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1960

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. — Price 25 cents

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1960

INTRODUCTION

The effective use of insecticides is dependent upon the availability of efficient and durable applicators. Many hundreds of sprayers, dusters, fumigators, and other devices have been designed, manufactured, and marketed; yet, equipment available today is generally inefficient and easily damaged. Acutely aware of this, manufacturers* are expending great effort in research and development, but efficient applicator equipment remains one of the great unsolved problems of public health engineering.

METHODS OF APPLYING INSECTICIDES. Insecticides may be applied as solids, liquids, or gases. SOLID FORMULATIONS are usually applied as **dusts** (by hand casting, shaker cans, foot pumps, hand-bellows, bulb dusters, plunger dusters, rotary dusters, power dusters). Solid formulations may also be dispensed as **granules, pellets, gelatinous capsules,** or **poison baits.** LIQUID FORMULATIONS may be applied by **hand** (pouring, dragging, dip cans, paint brushes, siphon atomizers, bucket pumps, pistol sprayers, compressed air sprayers) or by the use of **power** (pressure injection, aerosol "bombs," hose aspirators, hydraulic sprayers, mist generators, fog generators). GASEOUS FORMULATIONS are applied by fumigation techniques, pressure injection, or vaporization. Solids and liquids may also be applied by aerial **dispersion** (Brown, 1951; U. S. Department of Agriculture, 1955).

SELECTION OF SUITABLE APPLICATORS. Five key factors should be considered when selecting applicator equipment:

1. Will it do the job?
2. Is it safe?
3. Is it inoffensive?
4. Is it expensive?
5. Is it durable?

Effectiveness is essential. As has already been stated, the general efficiency of modern applicators is poor, but every attempt should be made to select the most effective equipment available. **Safety** should be a prime consideration in all insect control operations. Hazard to both the equipment operator and the general public should be evaluated. **Offensive applicator equipment** may do great harm to the public relations aspects of the insect control program. **Cost** is, of course, a primary factor, but in 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 may far exceed that of higher quality, more costly equipment. Durability of equipment should be balanced against cost, availability of repair, and degree of care that can be expected from workers who use it. More durable equipment is generally heavier, a factor which may be an important consideration (Entomological Society of America, 1957-8; National Sprayer and Duster Association, 1953; Symposium, 1959).

*Trade names are used throughout as a means of identifying the equipment under discussion, and their inclusion does not represent endorsement by the Public Health Service.

HAND SPRAYERS

Four types of hand insecticide sprayers are commonly used in public health operations: siphon atomizers, bucket pumps, pistol sprayers, and compressed air sprayers.

THE SIPHON ATOMIZER or "flit gun" is a familiar household item. A piston pump streams air over a small tube, aspirating the insecticide from the reservoir attached to the pump. The air blast breaks the insecticide into a fine mist. A continuous flow of insecticide is produced by some hand atomizers. As a general rule, these sprayers are designed to control flying insects in the home, but some may be modified for residual spraying. Pneumatic paint sprayers operate upon the same basic principle as the "flit gun," but are powered by an electric or gasoline motor. They are used for space spraying in commercial buildings where hand equipment would be inadequate. An example of their successful use is in the fogging of bakeries and other commercial establishments with pyrethrum solutions or emulsions. However, corrosive insecticide formulations may severely damage paint spray equipment.

THE BUCKET OR STIRRUP PUMP is the simplest and most inexpensive hydraulic sprayer. It is a plunger pump equipped with a spray hose, wand, and nozzle. This pump is inserted in a pail and operated continuously, by hand pumping, to produce a spray with pressures ranging up to 150 psi (pounds per square inch). This sprayer is not widely used in the United States, but it is the chief item of equipment in some foreign insect control programs.

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 of emulsion need be applied to cracks and crevices in buildings for cockroach and ant control. Pistol sprayers are especially designed to resist corrosive chemicals.

THE KNAPSACK SPRAYER, borne on the back of the operator, is supplied with webbing belts, 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 the treatment of small gardens, and to a lesser extent for mosquito larviciding.

Adjustable nozzles are usually standard equipment on these sprayers. ***The Trombone Sprayer*** is a modification of the knapsack sprayer in which the insecticide is drawn into a hose and discharged through the nozzle by a plunger and cylinder moving on each other with a trombone-like action.

THE COMPRESSED AIR SPRAYER is the mainstay of most public health insect control projects. Much care must be taken in selecting high quality sprayers as their high initial costs will be justified by their serviceability. The compressed air sprayer (figs. 3.1, 3.2) is a small 1- to 5-gallon cylindrical tank furnished with an air pump, hose, spray gun, and other components necessary for applying solutions, emulsions, or suspensions. The tank is filled 2/3 to 3/4 full of spray liquid, and air is compressed into the remaining space by means of a cylindrical air pump or other source of compressed air. This compressed air exerts pressure upon the liquid, forcing it from the sprayer through the delivery tube, hose, cut-off valve, and nozzle. The spray pattern will depend upon the air pressure maintained in the sprayer and the type of nozzle used. The air should be compressed to 50 psi, after which spraying may continue until pressure drops to approximately

30 psi. Then, pressure is again pumped to 50 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.

REGULATED PRESSURE COMPRESSED AIR SPRAYERS will supply solutions or emulsions at a constant, predetermined pressure. Before the regulated pressure sprayer is issued to spray operators, the pressure regulator should be set to maintain a 40 psi pressure. Many constant pressure sprayers of different capacities have been developed by personnel engaged in residual spraying operations. A sprayer suitable for treating large dairy barns and other buildings has been made of two 9-gallon stainless steel oxygen tanks. This sprayer may be skid-mounted or used on wheels. Larger truck-mounted compressed air sprayers have been developed using a large fluid tank and a smaller air tank connected to an air compresser operated by the fan belt of the vehicle. These larger sprayers are provided with two long leads of hose. Sprayers of this type are suitable for applying solutions and stable emulsions. Since no agitation is provided, it is not wise to use large compressed air sprayers for suspensions or quick-breaking emulsions.

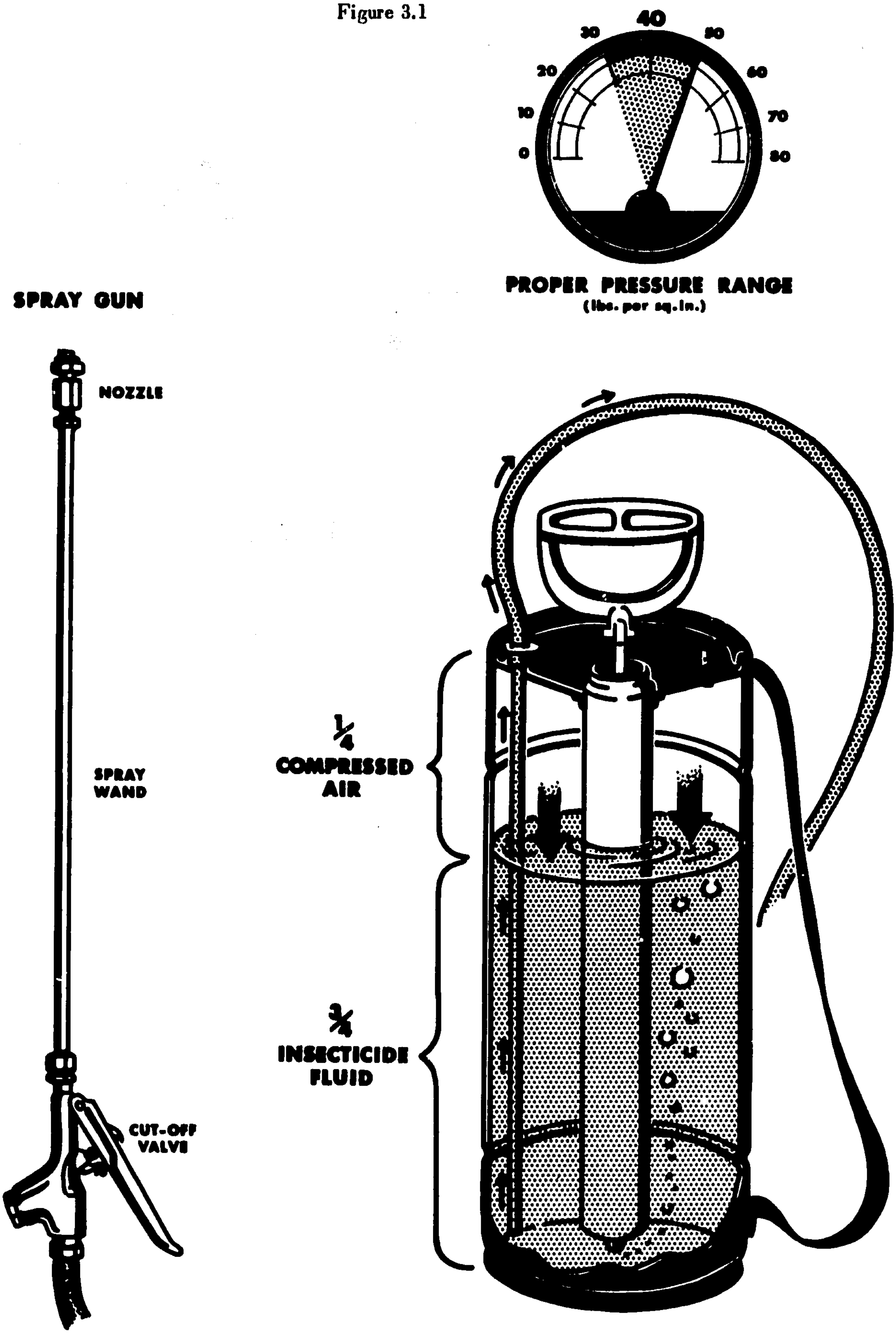
The tank of the compressed air sprayer is constructed of stainless steel, brass, or galvanized steel welded or soldered into a cylinder, with bottom and head of similar material. The galvanized tanks are comparatively inexpensive and are serviceable for applying water suspensions and some insecticidal solutions. Stainless steel tanks are resistant to the corrosive effects of chlorinated hydrocarbons such as chlordane, and will prove economical for continued use with emulsions or other corrosive mixtures. Stainless steel tanks fail mechanically as readily as galvanized tanks. Some stainless steel tanks, joined together with silver solder, have not proved serviceable because of small leaks at the soldered points. The electro-welded tanks are very satisfactory in this respect, although 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 sling 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 pet-cock may be welded into the head where it will not be broken off by rough handling. The air valve may 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 make of sprayer 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. Pressure gauges offered on most models do not remain serviceable long and are not essential. Spray operators soon learn to judge the correct pressure for spraying by the spray pattern and the amount of effort required to pump air into the tank.

The air pump consists of a handle, rod, 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

Figure 3.1



COMPRESSED AIR SPRAYER

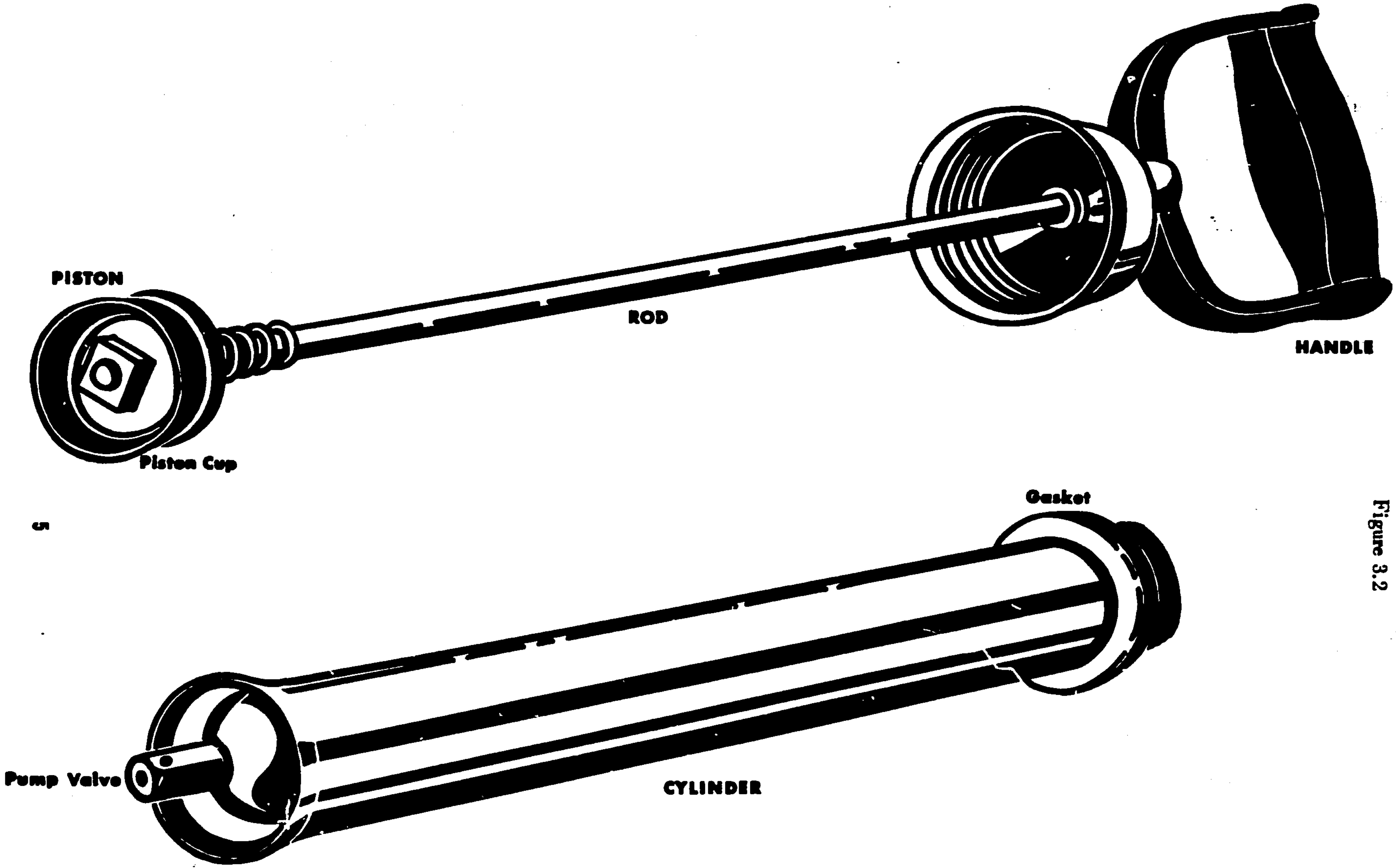


Figure 3.2

AIR PUMP
(Compressed Air Sprayer)

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 a synthetic rubber gasket. **All sprayers should be purchased with synthetic rubber gaskets if possible; if not, the natural rubber gaskets should be replaced with synthetic ones immediately to prevent trouble later.** 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 spray hose should be of **synthetic** rubber or plastic, 1/4-inch to 3/8-inch internal diameter, and **5 feet in length.** The short rubber hose provided with most 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 cut-off valve, a wand, and a nozzle. One manufacturer markets a simple ball valve that may be added to the wand to prevent drooling. This shut-off valve seats against the nozzle tip. Some high quality sprayers provide both a constant-pressure valve on the tank and a cut-off at the nozzle tip. The cut-off 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. There are few efficient cut-off valves on the market. Most of them leak on the operator's hands and will not effect a complete and rapid cut-off of pressure, thus causing drooling and dripping of the spray liquid. Some of the cut-off valves may be repacked with graphite-impregnated cord to prevent the insecticide from leaking onto the hands of the operator. Some valves have a small synthetic rubber gasket for this purpose.

The wand is a slender metal tube extending from the cut-off 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, cone, flat spray, coarse mist, or fine mist. 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. One orchard gun has a single nozzle adjustable from a solid stream to a fine mist by reducing the size of the whorl chamber. Adjustable nozzles produce a varied spray pattern by the same principle. However, **non-adjustable nozzles are desirable for public health operations,** as they may be depended upon to deliver a definite amount of insecticide per unit of time.

A readily available nozzle is a paint gun (fig. 3.3). However, unless specially constructed to resist corrosion, it will soon "freeze" and become useless.

Three nozzle types are recommended for the control of flies, mosquitoes, and other insects affecting the health of man:

(1) **The solid stream nozzle** which applies a fine jet of insecticide to treat cracks and crevices with chlordane, dieldrin, or lindane to control cockroaches, ants, etc.

(2) **The flat-spray nozzle** which distributes the insecticide in a thin band that issues fan-shaped from the nozzle opening. This nozzle, used chiefly for residual spraying, applies insecticide on surfaces much as a large paint brush would.

(3) **The hollow-cone nozzle**, which is used for mosquito larviciding. Cone nozzles with large apertures are employed for surface spraying of DDT suspensions and other materials. Most sprayers on the market are supplied with a hollow-cone nozzle for garden spraying.

A typical nozzle used for fly and mosquito control consists of a body, a locking nut, a screen, a tip, and a whorl chamber. The spray enters the nozzle body from the extension rod, goes through the strainer, and enters the whorl chamber, where it is made to rotate rapidly, and leaves the nozzle through a small aperture in the tip. The delivery rate depends upon the tank pressure and the size of the spray aperture. The size of the spray particles will depend upon the pressure, the aperture size, and the depth of the whorl chamber. Some nozzles have either interchangeable tips or aperture discs so that the tip alone requires changing in order to produce different spray patterns. Tips or discs, both comparatively inexpensive, may be replaced when damaged.

Most nozzles supplied with compressed air sprayers have a simple steel plate with a hole in the center called a nozzle disc 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 sprayer.

Several manufacturers have developed nozzle systems in which carefully calibrated nozzles are designated by number. Two of these, Teejet (tables 3.1 and 3.2) and Myers (table 3.3) will be used as examples.

TABLE 3.1 – TEEJET* NOZZLE SYSTEM

Nozzle Number	Spray Pattern and Angle	GPM at 40 psi**	Use
50015	Flat – 50°	.15	Residual spraying on very smooth surfaces
8002	Flat – 80°	.20	Residual spraying on ordinary surfaces
5004	Flat – 50°	.40	Residual spraying on porous surfaces
0001	Solid – 0°	.10	Cockroach control
2.55-56	Hollow cone – 56°	2.55 (gals. per hour)	Mosquito larviciding
Multeejet*** #5700 50015	Flat – 50°	.15	Residual spraying on very smooth surfaces
730039	Flat – 73°	.039	Mosquito larviciding
000021	Solid – 0°	.021	Cockroach control in fine homes or hotels
0001	Solid – 0°	.10	Cockroach control

* Spraying Systems, Inc., Bellwood, Illinois.
** Gallons per minute at 40 pounds per square inch pressure.
*** This nozzle has four different apertures.

Teejet nozzles are rated according to the angle at which the spray leaves the nozzle and to the output in tenths of gallons per minute or hour at a pressure of 40 pounds per square inch. Flat spray nozzles are designed for residual spraying. Mist nozzles produce an extremely fine mist that may be drifted with a slight breeze for 30 or more feet for mosquito larviciding. **It is important to use the proper nozzle for each type of application.**

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 percent chlordane emulsion is being used, the resulting dosage will be 100 milligrams per square foot. Should nozzles or nozzle apertures be 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 chlordane 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 3.2. 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 3.2 – APPLICATION RATES FOR TEEJET NOZZLES AT VARIOUS INSECTICIDE CONCENTRATIONS

Insecticide Concentration	Teejet Nozzle (insecticide deposit in milligrams/ft.²) 8001	50015	8002	5004
0.3 %	6	9	12	24
0.5	10	15	20	40
0.625	12.5	18.75	25	50
0.75	15	22.5	30	60
1.00	20	30	40	80
1.25	25	37.5	50	100
1.50	30	45	60	120
2.00	40	60	80	160
2.50	50	75	100	200
3.00	60	90	120	240
3.50	70	105	140	280
4.00	80	120	160	320
5.00	100	150	200	400
6.00	120	180	240	480
7.50	150	225	300	600
10.00	200	300	400	800

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

TABLE 3.3 – MYERS* NOZZLE SYSTEM

Nozzle 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.

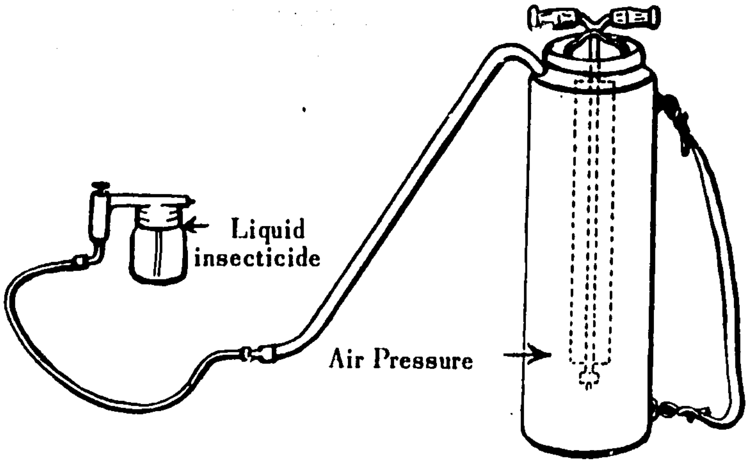


Figure 3.3 Compressed Air Sprayer with Paint Gun
for Nozzle

Figure 3.4 Hand Plunger Duster
in Use

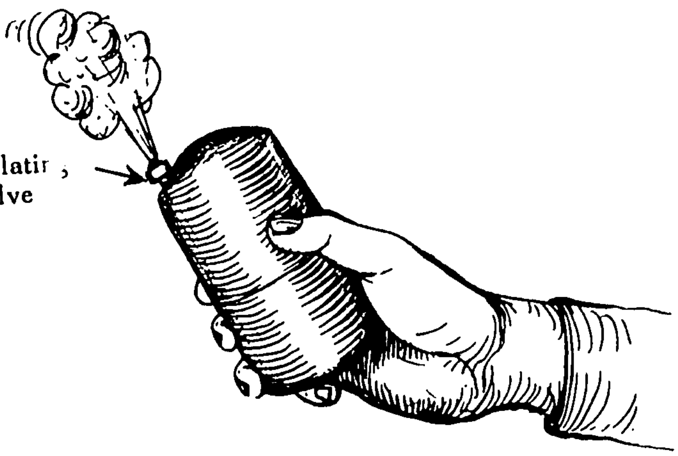


Figure 3.5 A Small Mist Generator
(Aerosol Bomb)

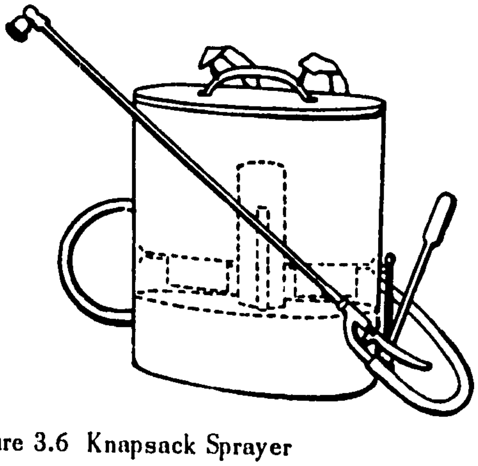


Figure 3.6 Knapsack Sprayer

HAND DUSTERS

HAND CASTING is a primitive but often highly effective method of applying insecticide dusts. If the diluent in the dust is pyrophyllite or talc, a handful of the material may be packed and thrown much like a snowball. This technique has been used efficiently in the control of rodent ectoparasites, particularly for putting dust on high or difficult-to-reach rat runways.

HAND SHAKERS are ideal for placing insecticidal dust on high **or difficult-to-reach areas.** A large shaker which holds five pounds of DDT dust has been used for dusting exposed rat runs along the base of walls or foundations. 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 (figs. 3.7, 3.8).

THE FOOT PUMP is a hand operated plunger type blower with a container for insecticide dust or fumigant. A stirrup is provided in order that the pump may 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 pumps are designed for applying calcium cyanide to rat burrows. This equipment is useful for applying dust to rodent burrows and other enclosed harborages (fig. 3.13).

THE HAND BELLOWS is a rubber cylinder (about 3 inches tall) with 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 excellent for indoor work where careful placement and neatness are essential.

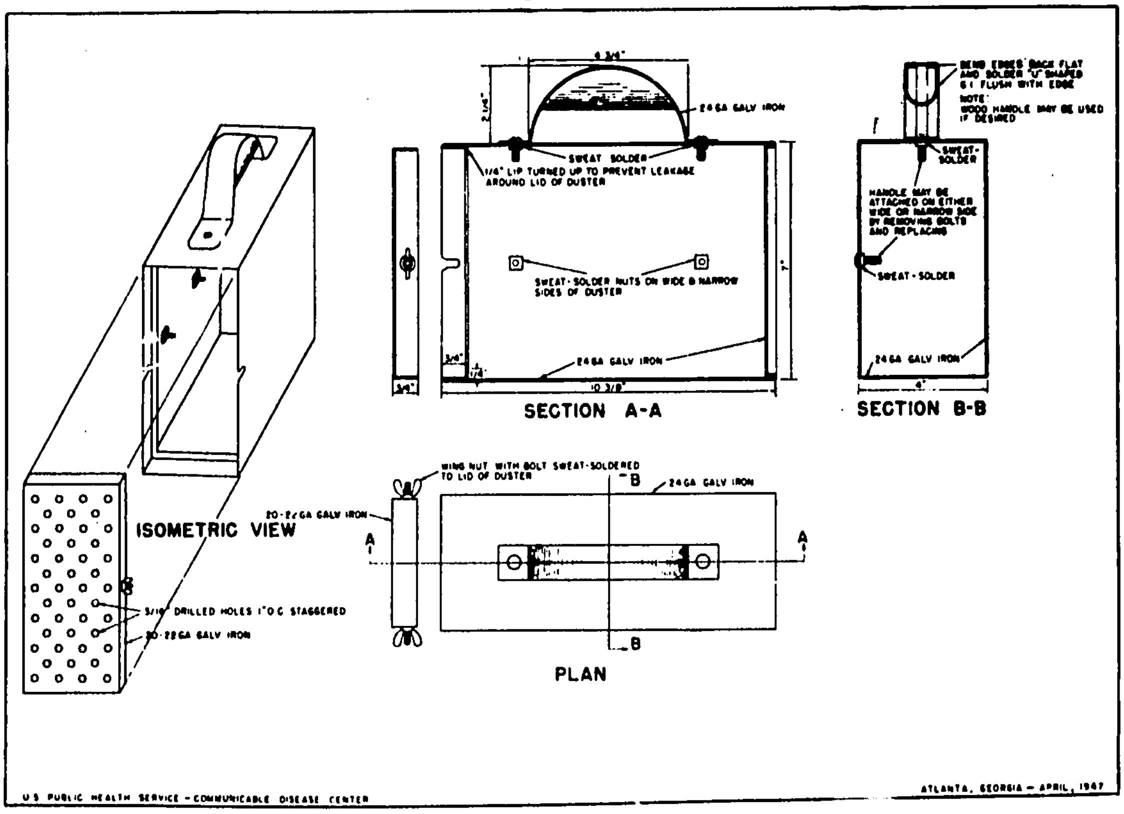
THE BULB DUSTER is also designed for careful indoor work. A 4-inch rubber bulb is fitted with a screw cup containing a dust nozzle. After the bulb is filled with dust, and the cap replaced, hand pressure on the bulb disperses the dust.

THE HAND PLUNGER DUSTER consists of 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 that the delivery tube is beneath the dust, very heavy dust patterns will be produced, suitable for making DDT patches for rodent ectoparasite control outdoors or in out buildings (figs. 3.4, 3.9).

THE KNAPSACK DUSTER figs. 3.6, 3.10) is a large bellows duster which may be mounted on the back of the operator.

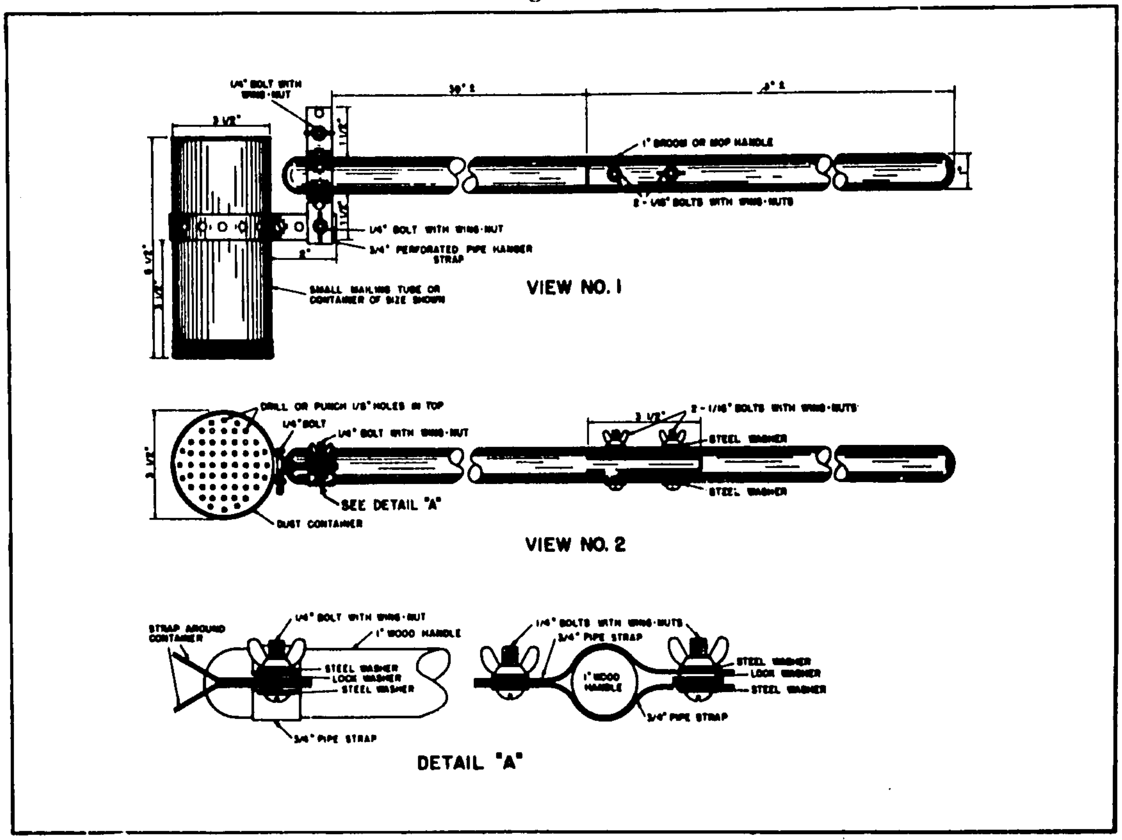
THE ROTARY DUSTER has a 5- to 10-lb capacity hopper from which dust is fed by a mechanism into a fan case. When the crank is turned, the fan blows the dust out through a long tube. Most dusters may be adjusted to deliver from 5 to 20 lbs. of dust per acre under normal conditions. Rotary dusters are used effectively for applying garden insecticides, for controlling fleas, ticks, and other ectoparasites around premises, and for applying dusts as mosquito larvicides. Some crop dusters are mounted on wheelbarrows, the power for the fan being supplied by the traction of the wheel.

Figure 3.7



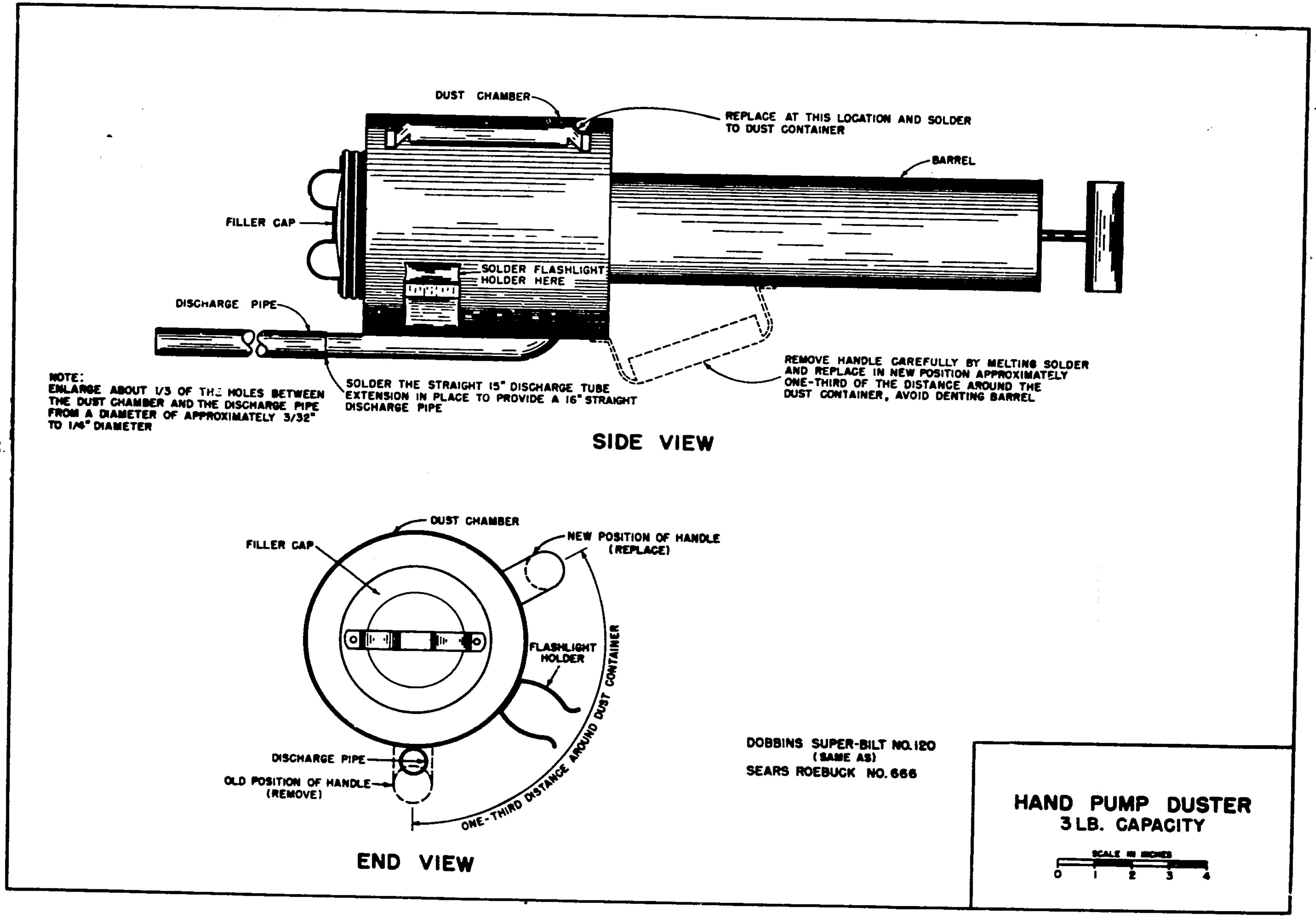
Fabrication details for a large hand shaker (5-pou capacity).

Figure 3.8



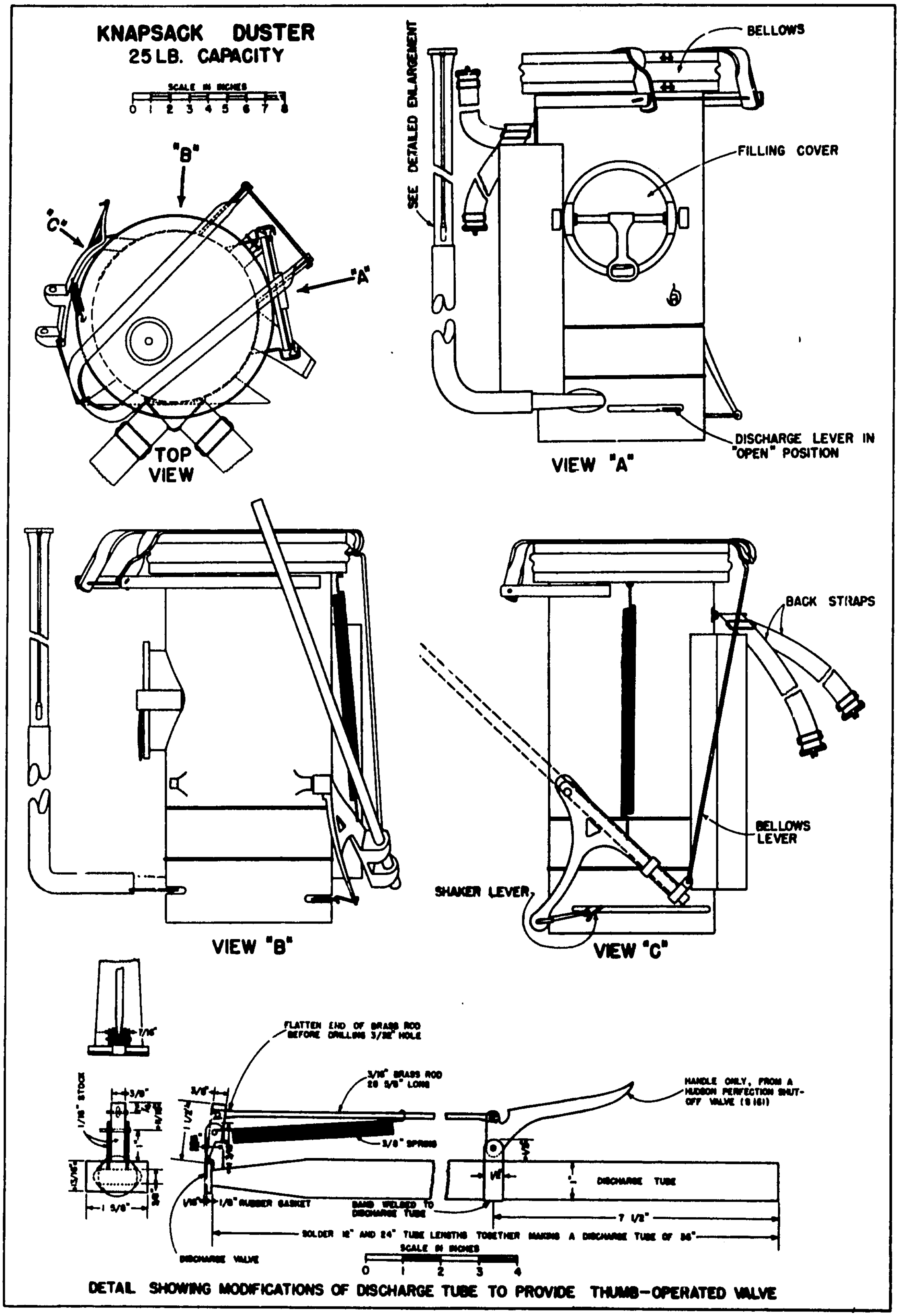
Fabrication details for a small hand shaker for reaching overhead rat runways.

Figure 3.9



DUST CHAMBER
REPLACE AT THIS LOCATION AND SOLDER TO DUST CONTAINER
BARREL
FILLER CAP
SOLDER FLASHLIGHT HOLDER HERE
DISCHARGE PIPE
NOTE: ENLARGE ABOUT 1/3 OF THE HOLES BETWEEN THE DUST CHAMBER AND THE DISCHARGE PIPE FROM A DIAMETER OF APPROXIMATELY 3/32" TO 1/4" DIAMETER
SOLDER THE STRAIGHT 15" DISCHARGE TUBE EXTENSION IN PLACE TO PROVIDE A 16" STRAIGHT DISCHARGE PIPE
REMOVE HANDLE CAREFULLY BY MELTING SOLDER AND REPLACE IN NEW POSITION APPROXIMATELY ONE-THIRD OF THE DISTANCE AROUND THE DUST CONTAINER, AVOID DENTING BARREL
SIDE VIEW
DUST CHAMBER
FILLER CAP
NEW POSITION OF HANDLE (REPLACE)
FLASHLIGHT HOLDER
ONE-THIRD DISTANCE AROUND DUST CONTAINER
DISCHARGE PIPE
OLD POSITION OF HANDLE (REMOVE)
END VIEW
DOBBINS SUPER-BILT NO. 120 (SAME AS) SEARS ROEBUCK NO. 666
HAND PUMP DUSTER
3 LB. CAPACITY
SCALE IN INCHES
0 1 2 3 4

Figure 3.10


KNAPSACK DUSTER
25 LB. CAPACITY
SCALE IN INCHES
0 1 2 3 4 5 6 7 8
"B"
"C"
"A"
TOP VIEW
SEE DETAILED ENLARGEMENT
BELLOWS
FILLING COVER
DISCHARGE LEVER IN "OPEN" POSITION
VIEW "A"
BACK STRAPS
BELLOWS LEVER
SHAKER LEVER
VIEW "B"
VIEW "C"
FLATTEN END OF BRASS ROD BEFORE DRILLING 3/32" HOLE
3/16" BRASS ROD 28 5/8" LONG
HANDLE ONLY, FROM A HUDSON PERFECTION SHUT-OFF VALVE (S161)
3/8" SPRING
DISCHARGE TUBE
1/16" STOCK
1 5/8"
1/8" RUBBER GASKET
BAND WELDED TO DISCHARGE TUBE
7 1/2"
SOLDER 12" AND 24" TUBE LENGTHS TOGETHER MAKING A DISCHARGE TUBE OF 36"
DISCHARGE VALVE
SCALE IN INCHES
0 1 2 3 4
DETAIL SHOWING MODIFICATIONS OF DISCHARGE TUBE TO PROVIDE THUMB-OPERATED VALVE

POWER SPRAYERS AND DUSTERS

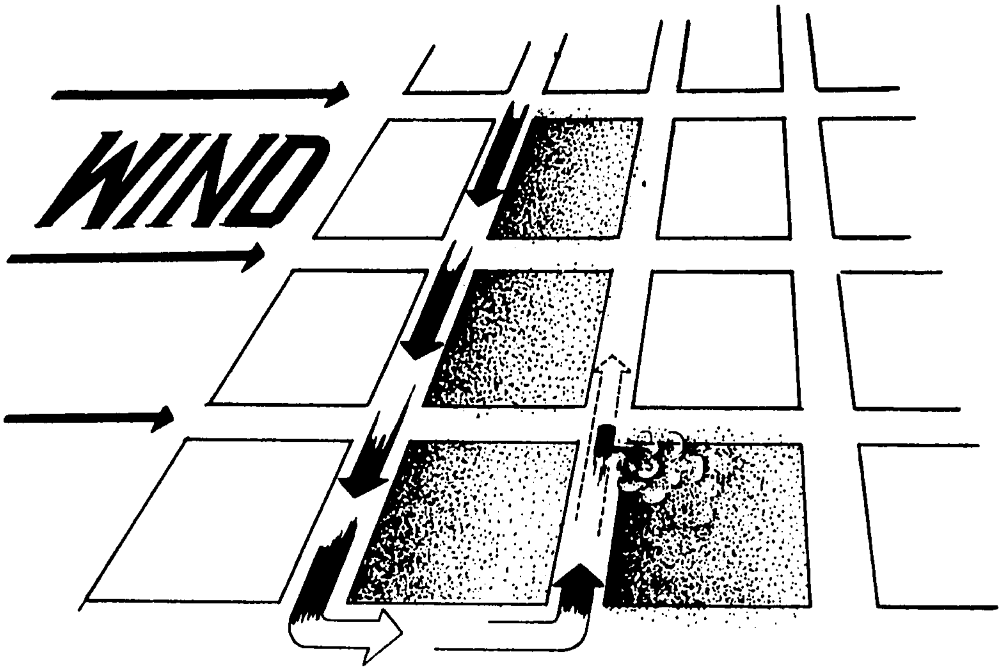
HYDRAULIC POWER SPRAYERS include most of the agricultural sprayers, such as equipment used for orchard, shade tree, and livestock operations, and the broom sprayers used for treatment of field crops. The spray liquid is pressurized by means of a power driven hydraulic pump with suitable regulators provided 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 ¾- to 1½-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.

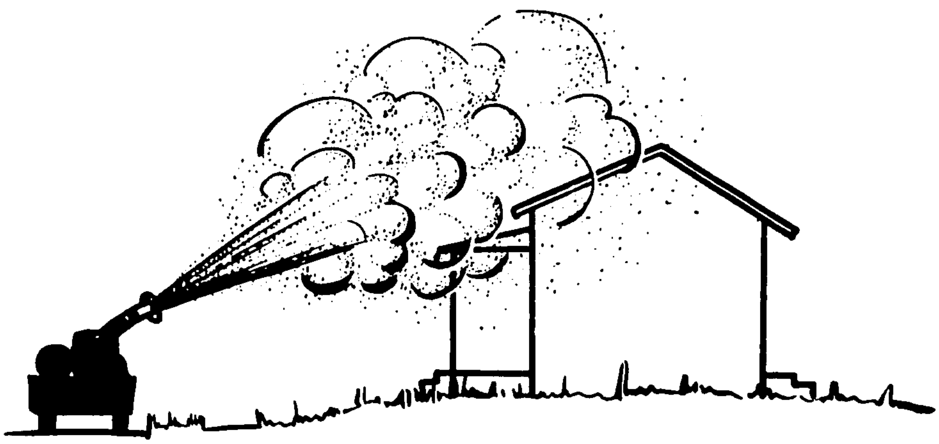
There is a general tendency toward using equipment heavier than is required for an operation. A large sprayer with a 500-gallon tank and an output of 35 gallons per minute (gpm) is not suitable for the usual public health operations. Small compressed air sprayers are best for most insecticide applications within the home, whereas 50- to 150-gallon power sprayers are more suitable for extensive treatment of fences, porches, and out buildings. 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-foot 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 ½ inch internal diameter hose is more suitable for long leads such as this, as it is more rugged and will cause lower friction losses than the ¼ inch hose.

MIST AND FOG APPLICATORS are used for space spraying with contact insecticides. Large mist and fog machines control insects out of doors by the same principle as that utilized by hand sprayers and aerosol dispensers in the home – contact killing. In urban space spraying for fly and mosquito control, the city block is the unit treated. The machines are operated in the streets and through the alleys to produce a complete blanket or DDT, lindane, malathion, or other insecticide. Application rates of as low as 0.3 to 0.5 pounds of DDT per acre have given effective control of mosquitoes and susceptible flies. Most large fog machines adjust to put out 15-40 gallons per hour, while large mist machines adjust to put out 6-50 gallons per hour (some up to 3,000 gallons per hour). As a general rule the machine moves at a rate of 5 miles per hour. The insecticide must be dispersed downwind, as a light breeze will facilitate treatment of an effective swath 100 to 200 feet deep. The effective swath is much deeper in open woodlands and other areas where buildings and other structures offer no obstruction to horizontal air currents (fig. 3.11).

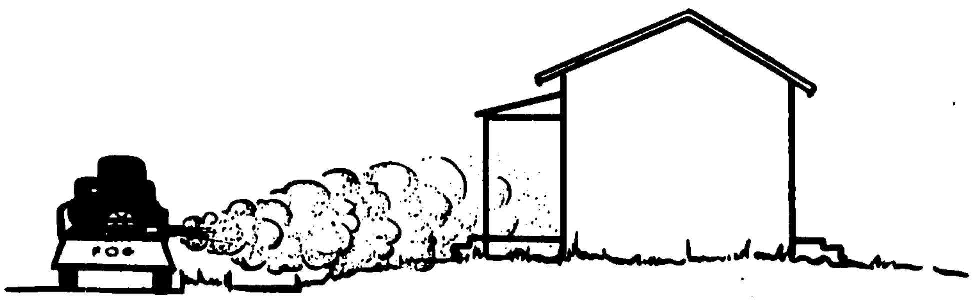
Figure 3.11
OUTDOOR SPACE SPRAYING



1. Treat block by block.



2. Mist is directed over housetops.



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

Mists and Fogs: **A mist** is composed of particles of sufficient size to settle to the earth despite the unfavorable thermal currents ordinarily encountered (fig. 3.5). **A fog** has much finer particles that will remain suspended for a long period of time, settling only in relatively still air. Spray particles are so extremely small that a convenient unit of measurement, the micron, is used. The micron is 1/1,000 of a millimeter, or roughly 1/25,000 of an inch. Glasgow (1947) measured the particle size of different well-known natural phenomena and arrived at the following figures:

Type	Average Diameter of Droplets (microns)
Rain	4,000
Drizzle	400
Mist	40
Fog	4
Cloud	0.4
Smoke	0.1-0.01

These figures should not be taken too literally to represent the size of the spray particles put out by the different mist and fog applicators, for, of course, they vary. The thermal aerosol generator, for instance, may put out particles ranging from a smoke to a mist, while a mist blower may produce particles ranging from 10 to more than 200 microns. Thus it is important to know the "mass median diameter" – the predominant particle size – of a given mist or fog in order to describe that characteristic of each machine accurately.

The mists settle fairly rapidly, but remain suspended in the air for a sufficient time to cover a 200-foot swath with only a light breeze to promote distribution. This settling will occur despite the fact that there are thermal currents rising from the heated earth during the daytime hours. This condition is in contrast to that produced by the fog applicators when they are adjusted to put out extremely fine particles. Particles 10 microns or smaller in diameter are likely to rise rapidly in thermal currents during the daytime and produce little or no kill of insects during that 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 (table 3.4).

TABLE 3.4 – SETTLING RATES OF SPRAY AND FOG PARTICLES

Droplet Diameter	Rate of Fall	Time Required to Fall 1 Foot
100 microns	1 ft./sec.	1 second
10 microns	1/8 in./sec.	1–2/3 minutes
1 micron	30 microns/sec.	2–3/4 hours
0.1 micron	0.3 micron/sec.	11–1/2 days

Water suspensions of insecticide will be emitted in coarser particle size than the oil sprays. The light oils, such as kerosene, produce small particle sizes, whereas oils of higher viscosity produce much larger particles. Several machines on the market produce particle sizes with a mass median diameter ranging between 40 and 70 microns using light oils. Particle size may be varied by use of more vs. less air velocity, fine vs. coarse spray nozzles, or light vs. heavy spray oil.

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 incidence. 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.

MIST BLOWERS were developed originally from power dusters used on crops. A large air fan produces a column of wind into which liquid insecticide is injected. The air blast "atomizes" the liquid and carries it into the target area. The rate of spray emission varies from about 0.6 gpm with small portable mist blowers, to 50 gpm with large sprayers. The blowers fall into two classes: the radial fan type and the axial flow air turbine.

RADIAL FAN MIST BLOWERS can be revolved 360° horizontally and the air nozzle adjusted 360° vertically. With a dynamically and statically balanced fan operating at 2,900 rpm, one machine emits 8,000 cubic feet of air per minute at 150 miles per hour through a 10-inch air nozzle; weighs 1,400 lbs.; and occupies a mounting area of 5½ x 6 feet. It can be carried on a ¾-ton truck. Baffle plates in the wind tunnel limit turbulence and add distance to the projection of spray material. The 42-horsepower engine provides power to turn the fan and a small spray pump. Agitation in the welded steel tank is obtained by recirculation of surplus spray material. A smaller model, weighing only 700 lbs., may be mounted on a light truck or trailer, and is powered by a 13.3-horsepower aircooled engine. In some radial fan mist blowers, insecticide is delivered to shear plates, thus eliminating the need for small nozzle openings that might become clogged. With some, a hopper is provided so that dust as well as liquid may be used. The controls are centrally located on an instrument board within easy reach of the operator.

AIR TURBINE MIST BLOWERS have an advantage in the application of suspensions, as a cadmium-plated mechanical agitator is mounted in the spray tank. The air turbine mist blower may be used for applying liquids, dusts, or a combination of the two. The turbine blower operated at 3,800 rpm produces 4,000 cu. ft. of air per minute at velocities up to 250 mph. This sprayer produces a somewhat coarser mist than the machines discussed above, the mass median diameter of oil sprays often being in excess of 100 microns. One make, complete except for turntable, weighs approximately 800 lbs. It may be mounted on a jeep, permitting one-man operation.

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 1,500 feet 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, 2, 4-D and 2, 4, 5-T weed killers 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. The above machines have been used as examples of different types of equipment, and may or may not be superior to other available makes. 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. Table 3.5 lists acres-per-hour coverage for different swath widths and speeds of mist and fog applicators.

TABLE 3.5 – COVERAGE RATES FOR MIST AND FOG APPLICATORS

Rate of Travel (MPH)	Number of Acres Covered per Hour for Swaths of 50 feet	100 feet	200 feet	300 feet
3	18	36	72	108
4	24	48	96	144
5	30	60	121	181
6	36	72	144	216

THE MECHANICAL FOG GENERATOR breaks up the insecticide into fine particles by mechanical means. 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 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 drive shaft shears off the insecticide droplets and blows them forward at a high velocity. For space control of insects in dairy barns, bakeries, and other buildings, a small model has been developed to use contact insecticides such as the pyrethrins. From ½ to 2 ounces of liquid per 1,000 cu. ft. may be applied, depending upon 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 (Brown, 1951). One large mechanical fog generator has many discs instead of the 2 discs in the small model. The spray blast can be elevated 20° vertically and rotated 360°, while the rate of application is adjustable from 0 to 250 gallons of insecticide per hour. Power is supplied by an 8 horsepower 4-cycle gasoline engine. In field tests of the large unit, from 60 to 90 acres of corn were sprayed per day, with as much as 150 acres covered on a single day. When the 8-inch discs are rotated at 6,500 rpm and solution is emitted at 4.5 gpm, the air blower produces 4,500 cu. ft. of air per minute. This machine, as well as the thermal aerosol machines, is dependent upon favorable air currents for distribution of the insecticide.

THERMAL FOG GENERATORS break up the insecticide by means of hot gases or superheated steam. The simplest form is the exhaust generator mounted on a portable gasoline engine or upon a jeep exhaust pipe. Insecticidal oil is injected into the exhaust generator by means of a small copper tube. If a venturi tube is used, the insecticide is released at the throat of the venturi, where the exhaust gases have a maximum velocity. The particle size of the emitted spray can be increased to a mist or reduced to a smoke by permitting a greater or lesser flow rate of the solution. When used with a 40 horsepower jeep engine and a flow rate of 10 gallons per hour, an aerosol with a mass median diameter of about 25 microns is obtained; whereas with a flow rate of 50 gallons per hour, a wet fog or mist containing droplets as high as 250 microns in diameter is dispersed. However, the use of a venturi with the generator on an automobile engine results in greatly increased wear to the engine. Commercial products have been developed for large insect control programs. In one fog machine an air-cooled motor is employed to run the air pump, the fuel pump, and the insecticide pump – the only moving parts of the equipment. Air is delivered at 150 cu. ft. per minute by a rotary pump and passes into a combustion chamber where it is heated by gasoline combustion to a regulated temperature between 800 and 1,200° F. The hot gases 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 into a cup situated in the fog head where it is "atomized" by the blast of hot gases.

Normal insecticide delivery rate is 30 to 45 gallons per hour for a heavy fog or a fine mist. Excess insecticide delivered by the pump is recirculated into the insecticide tank. If the delivery rate is increased from 10 gallons per hour to 50 gallons per hour, the mass median diameter of the resulting aerosol is increased from 5 microns to 50 microns. Tests have shown that there may be some decomposition of the insecticide due to heat; even DDT showed 35 percent destruction in oil solution. This loss may be minimized by using less volatile oils. The use of high flash point oils will reduce the possibility of explosion. No. 2 fuel oil is suitable for most space spraying operations, as it will produce a heavier fog than kerosene. Applications should be made in the evening and morning when surface temperature inversion occurs. At such times, the air temperature near the ground is somewhat cooler than it is above a 6 ft. elevation. Under these conditions, the fog will remain for a long period of time near the ground where mosquitoes are abundant, rather than rising on thermal currents to elevations where it will be of no practical value.

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 lbs. Gasoline is burned at the rate of sixty explosions per second, producing hot exhaust gases. An oil solution of insecticide is introduced into the exhaust pipe where it is "atomized" and partially vaporized by the scrubbing action and heat of the gases. The insecticide is forced into the tank under 6 psi pressure tapped from the engine head, and the rate of flow is determined by a formulation valve. Particle size may be regulated by adjusting the flow of insecticide from 0 to 45 gallons per hour, the latter rate producing droplets with a mass median diameter as high as 75 microns, 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 (Brown, 1951). 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.

THE STEAM FOG GENERATOR was developed from the ordinary steam jenny used for steam cleaning heavy equipment. In fact, it may be used for steam cleaning garbage trucks on a city program. Super-heated steam is generated in a stainless steel coil and passed out of the machine through one or more nozzles. An insecticide under low pressure is injected into this high velocity steam blast with a resultant shearing of the liquid to produce an insecticidal fog. It is possible, by changing coil temperatures and by using different insecticidal liquids, to obtain particle sizes ranging from 10 to 100 microns mass median diameter. This machine, in common with other fog applicators, will not stain automobiles and windows when it is properly operated.

Experience indicates that the particle size of an aerosol should be 10 or more 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. Table 3.6 is offered only as an example of a method of figuring costs. Other items, such as insurance, mixing time, and supervision, should be considered when computing costs. Should two men be used for the operation, it would be necessary to add two dollars more to the per-hour expense.

Technical grade materials are used for 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 the emulsions do not produce a satisfactory fog.

The cost per acre is lower in areas where a 200-foot swath width is possible. The 100-foot swath width is used in the table as a more conservative figure for cities where buildings, fences, and other structures deflect the mist or fog and reduce the effective swath width. The 15-gallon-per-hour figure is used as this application rate is typical for mosquito adult control in some areas. This will produce a dosage of one quart per acre when the machine is operated at 5 miles per hour with a 100-foot swath depth. Heavier applications of chemical can be computed in the same manner, increasing the costs for insecticide and solvent accordingly.

TABLE 3.6 – EXAMPLES OF PER HOUR COSTS FOR SPACE SPRAYING
(100 ft. swath applied at 5 miles per hour)

Insecticide Used	Base Chemical	Unit Cost	Chemical Cost	Solvent Costs	Overhead* Costs	Cost per Hour	Cost per Acre
		Mosquito Control**			15 gals./hour		60 acres/hour
5% DDT sol.	tech. DDT	$ .40/lb.	$ 1.92	$3.00	$7.40	$12.32	$.21
5% DDT sol.	25% sol.	1.77/gal.	5.31	3.00	7.40	15.71	.26
5% DDT emul.	Emuls. conc.	1.77/gal.	5.31	0	7.40	12.71	.21
1% lindane sol.	tech. lindane	6.00/lb.	6.00	3.00	7.40	16.40	.27
1% lindane emuls.	20% conc.	15.20/gal.	11.40	0	7.40	18.80	.31
0.5% lindane sol.	tech. lindane	6.00/lb.	3.00	3.00	7.40	13.40	.22
0.5% lindane emuls.	20% conc.	15.45/gal.	5.70	0	7.40	13.10	.22
5% chlordane sol.	tech. chlor.	.77/lb.	3.85	3.00	7.40	14.25	.24
5% chlordane emuls.	46% conc.	4.20/gal.	6.85	0	7.40	14.25	.24
2% chlordane sol.	tech. chlor.	.77/lb.	1.54	3.00	7.40	11.94	.20
2% chlordane emuls.	46% conc.	4.20/gal.	2.73	0	7.40	10.13	.17

* Overhead includes depreciation and maintenance $2.00; labor $2.00/hr; gasoline $.90; and contingencies $2.50.
**For fly control, multiply insecticide and solvent costs by 3 for a 45 gal./hr. application.

POWER DUSTERS of various sizes have been developed for treating people with DDT dust for control of lice during a typhus epidemic. The army compressed-air duster consists of an air-cooled engine operating a compressor which is connected to 12 hose leads. Those hose leads supply compressed air to small hand dust applicators for the rapid treatment of louse-infested persons.

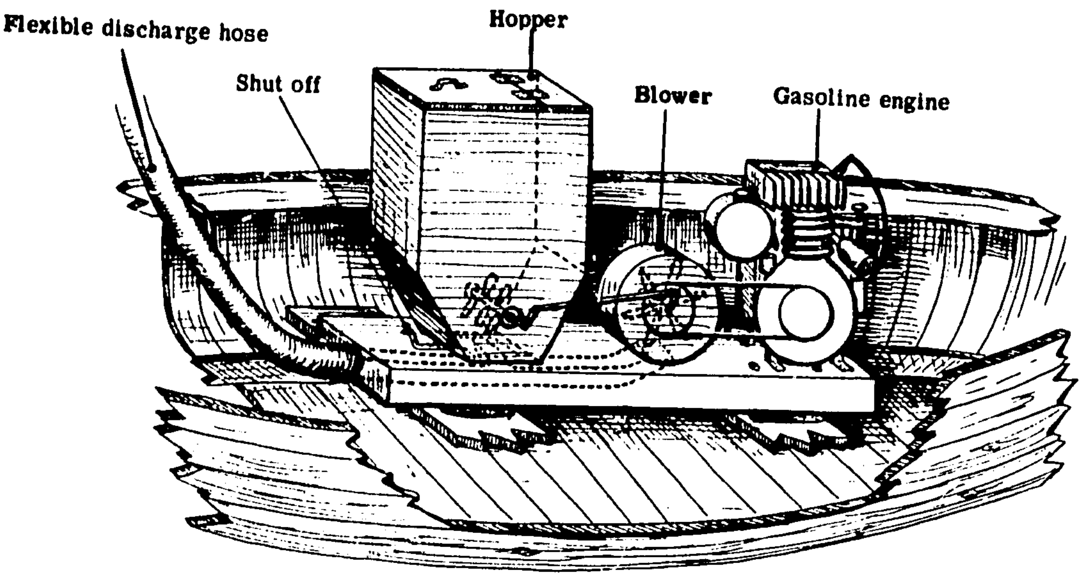


Figure 3.12 Boat-Mounted Power Duster

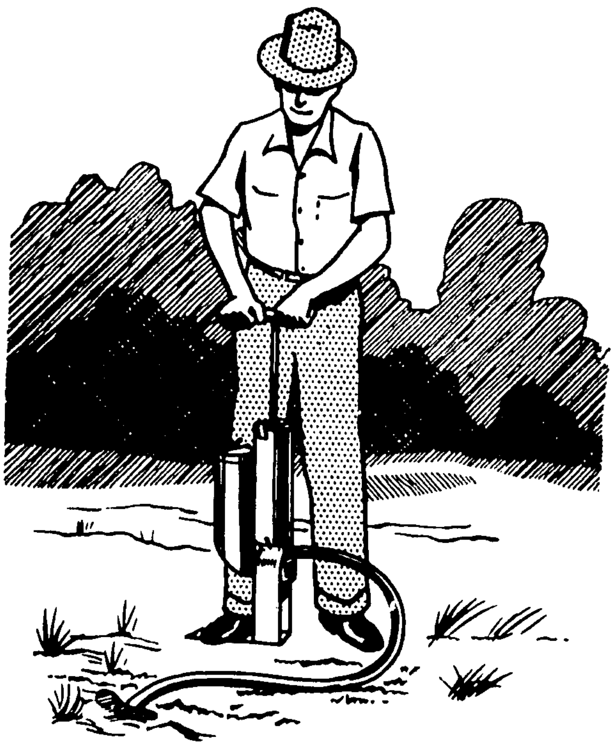


Figure 3.13 Cyanide Foot Pump

The usual power duster consists of a dust hopper with a large radial fan operated by a gasoline engine and carrying from 1 to 6 air nozzles. They are now in common use for treating orchard trees and row crops. The single nozzle type would be especially valuable during a typhus or plague epidemic. Both the Buffalo Turbine and the Bean. Rotomist can be used as dusters and, in fact, were originally adapted from power dusters to permit the application of concentrated sprays. Boat-mounted power dusters are especially useful for mosquito larviciding (fig. 3.12).

FUMIGATION EQUIPMENT

FUMIGATION, the filling of enclosed spaces with poison gas, was the primary method of household and industrial insect control from 1898 to 1945. Although fumigation has been largely replaced by the use of chemical sprays and dusts, great quantities of fumigants are still used for elimination of insects and rodents from:

(1) Railroad box-cars.
(2) Ships.
(3) Aircraft (under certain conditions).
(4) Food storage warehouses (particularly grain storage structures).
(5) Food processing plants.
(6) Greenhouses.

In addition, fumigation of rodent burrows and control of termites with fumigants are recommended under certain conditions.

Hydrogen cyanide and **methyl bromide** are the fumigants most commonly used. BOTH MATERIALS ARE HIGHLY TOXIC TO MAN AND SHOULD BE USED ONLY BY RESPONSIBLE WELL-TRAINED PERSONNEL. Instructions on the use of these materials may be obtained from the manufacturer.

Cyanide is sold as the sodium or calcium salt which is readily transformed to hydrogen cyanide by moisture in the air. The material comes in various forms to facilitate safety and efficiency. The American Cyanamid and Chemical Corporation, one of the largest retail producers of cyanide, markets it in the following forms: (1) **A-Dust** is finely ground powder suited for application with a **foot pump.** This is used in public health work to fumigate rodent burrows. (2) **G-Fumigant** is comparable to sea sand in size and is used for fumigating warehouses, flour mills, and grain storage buildings. (3) **Granular Fumigant** (slightly coarser than G-fumigant), (4) **Fumigant Flakes** (large, flat particles), and (5) **H-Dust** (a mixture of A-Dust and G-Fumigant) are not used in routine public health operations. (6) **Discoids** consist of hydrogen cyanide absorbed in an inert porous absorptive material such as wood or paper pulp cut out in the form of these discs. The discoids are removed from a sealed can, scattered about the floor of a building, and the gas escapes and fumigates the area.

Hydrogen cyanide has a distinctive "bitter almonds" odor, boils at 78.8° F., freezes at 6.8° F., and is slightly lighter than air (S.G. 0.93). It is soluble in all proportions in air. When used as recommended, no fire hazard is involved with cyanide; and no injury will occur to most stored foods or other items.

Methyl bromide is sold in cylinders or cans. It is odorless, boils at 40.1° F., freezes at 135.4° F., and is much heavier than air (S.G. 3.27). It is essentially insoluble in water and noninflammable when used as directed. It is more penetrating than cyanide.

Equipment used in fumigation includes (1) **crocks,** (2) **cyanide generators,** (3) **Franklin moisture traps,** (4) **fumigation vaults,** and **foot pumps.** Safety equipment (**gas masks, gloves, antidotes, warning signs,** etc.) must be provided. Only the foot pump is commonly used today by public health workers in the field.

CYANIDE FOOT PUMPS are of two types. One is equipped with a glass for holding about three-quarters of a pound of material and is suitable for treating about 36 rodent burrows with one filling. The second is equipped with a five pound reservoir which is sufficient for treating about 250 burrows at one filling (fig. 3.13).

OTHER MEANS OF APPLICATION

POURING of chemicals may be of value under certain conditions. Measured amounts of insecticide may be poured into fast-moving 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 of public health importance. Calculations should be made to assure adequate control without damage to fish or other wildlife. Do not pollute water supplies which will be used by human beings (fig. 3.14).

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 water than in still water (fig. 3.15).

PAINT BRUSHES are very effective for applying controlled amounts of insecticide to areas where insects hide or run. They are especially suited to household insect control because there is less chance of damaging materials and greater safety than with sprayers.

GRANULE DISPERSION with dusters, by hand, or by aircraft may have advantages over applications of sprays or dusts. The chief benefit is that the granules do not stick to foliage or other overhanging matter, but bounce on downward to the ground or water surface.

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.

POISON BAITS are little used today in public health insect control. However, under certain conditions, poisoning of bran or other food and scattering it out for insect control may be desirable. For example, poison bran is routinely used for locust control.

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.

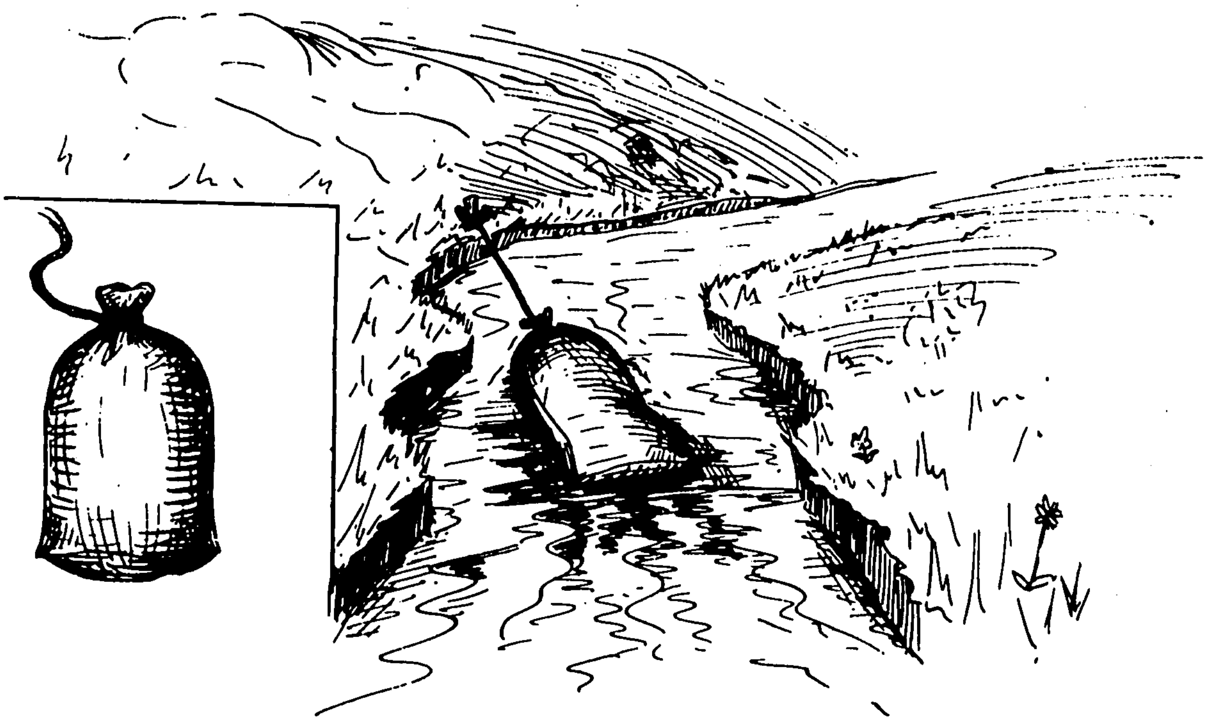


Figure 3.14 One Method of Dragging

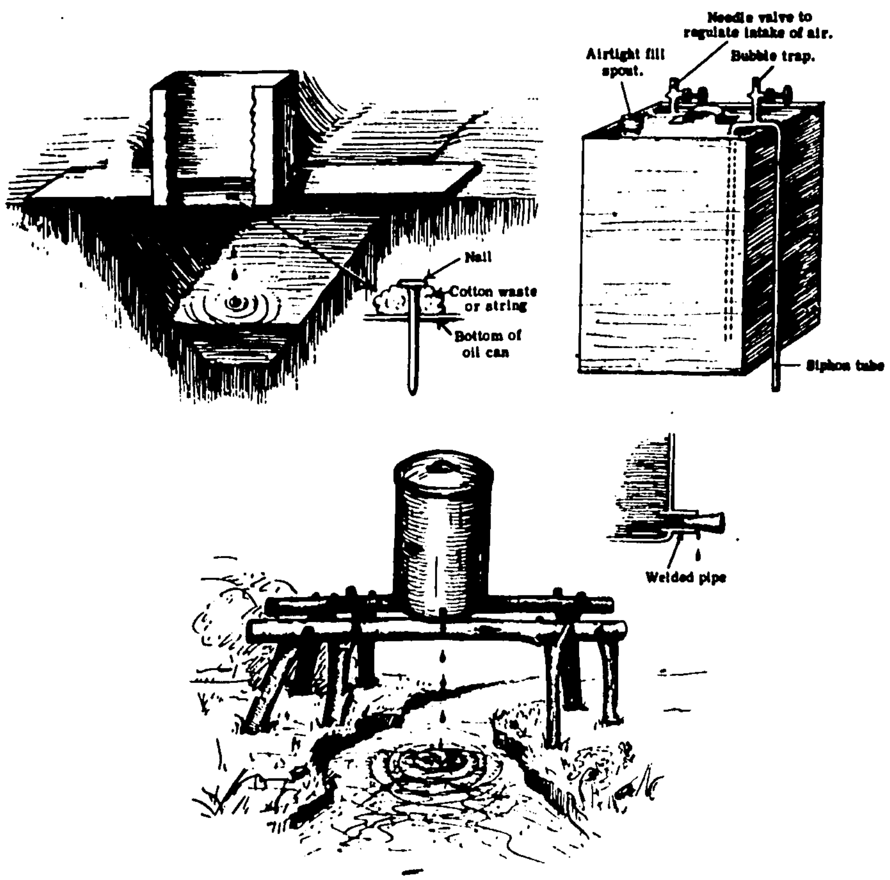


Figure 3.15 Drip Cans

VAPORIZERS put insecticide into the air in the same manner as a vaporizer used to humidify and medicate air in a room where a person has a respiratory ailment. The safety of insecticide vaporizers to human beings is questioned, and they are not recommended for use anywhere exposure will be relatively continuous to personnel involved.

AERIAL DISPERSAL OF INSECTICIDES

(Adapted from U. S. Air Force Manual 90-4)

Aerial dispersal is the distribution of insecticides from aircraft according to an established plan to obtain maximum efficiency in insect control. Scientific aspects of aerial spray operations must be kept in mind at all times since effective aerial spraying is dependent upon the care and precision with which it is carried out. Establishment of the need for spraying involves knowledge of the species involved (including life history, and behavior) and delineation of the areas infested by the species. To obtain uniform coverage of an area, careful observance of preplanned flight patterns, altitudes, and air speeds is essential. Operation at excessive altitudes or in high winds causes dissipation of the insecticide, resulting in insufficient chemical reaching the control area. These operations may also result in drifting of spray material with possible damage to adjacent property or wildlife. Changing air speed will change rate of application, spray pattern, and swath width. The short period of susceptibility in the insect's life cycle may require coverage of a large area in a very limited time.

Aerial spraying results primarily in control of insects exposed at the time of application. It is not adequate for the control of constantly emerging insects. Unlike careful ground control, aerial spraying does not permit coverage of undersurfaces and, as is the case with any insecticidal treatment, is not a long-range substitute for such permanent measures as drainage, filling, and good sanitary practices. Weather (high winds, heat thermals, low ceiling, and low visibility) may limit use of aerial spraying equipment. Early morning or just before dusk is the most effective time to accomplish aerial spraying. Because aerial spraying is expensive, costs of modification and operation of necessary aircraft should be weighed carefully against the cost of ground control before a spraying program is planned. The cost of aerial spraying of small areas is usually prohibitive. Effective aerial spraying can be accomplished only by flying at low altitudes. Terrain and major obstructions may therefore limit spraying operations. Major deviation from standard spraying procedures to avoid obstructions nullifies the benefits of aerial spraying. Possibility of endangering wildlife must be taken into consideration. Water movement frequently causes eventual concentration of oil-base insecticides in a relatively small area. Birds and mammals are not usually affected by insecticides at normal deposit rates but may be endangered by higher rates. Reduction in the insect population may force insectivorous species to abandon an area. Most insecticides must not be used on vegetation intended for grazing. Property damage is also possible since spray droplets may spot laundry and automobiles, but permanent damage is infrequent. Heavy application of oil-base insecticides may injure vegetation.

Aerial dispersal of insecticides permits quick coverage of large areas. When time is of the utmost importance to prevent massive infestation or an outbreak of disease, aerial spraying is often the only practical measure to effect control. It also permits coverage of terrain (such as an extensive marsh) inaccessible to ground equipment.

CARE AND MAINTENANCE OF APPLICATOR EQUIPMENT

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

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

SPRAYERS generally present 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 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 (washing soda), 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.

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.

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