INSECTICIDE APPLICATION EQUIPMENT FOR MOSQUITO CONTROL

Portions of this chapter were obtained from the University of Florida and the American Mosquito Control Association at the Public Health Pest Control web site at http://vector.ifas.ufl.edu/ .

RELATIONSHIP BETWEEN PESTICIDE APPLICATION AND PARTICLE SIZE

It is important to understand the relationship between the types of applications utilized in public health pest control and particle size. The effectiveness of a pesticide is influenced by the size of the droplets or particles applied and the equipment that is used for the application. For example, with residual applications the intent is to create a persistent deposit, which usually calls for medium to large size droplets. But for an area application against adult mosquitoes or flies on the wing, aerosols with smaller droplets are used so that the insecticide will remain suspended in the air longer and thereby extend the period of target exposure to the droplets.

Liquid sprays range from rain-like drops to mists and fogs produced by specialized generators. It may be impractical, if not impossible, to break up a liquid into entirely uniform droplets. But specialized equipment configurations can be used to restrict the range of droplet sizes. The usual practice to characterize these droplets is to refer to the mass median diameter (mmd) of the spray, which is the droplet diameter size that divides the volume or mass of the spray into two equal portions. The unit of measurement is the micron, 1/1000 of a millimeter or about 1/25,000 of an inch. The average diameter of a human hair is about 100 microns. Liquid applications may be categorized as follows:

- **Coarse** sprays contain droplets 400 microns or more in diameter that are produced with coarse disc nozzles or solid-stream gun nozzles. These droplets remain aloft for only a brief period.
- **Fine** sprays have droplets ranging from 100 to 400 microns, usually produced with hollow-cone and fan-spray nozzles. These droplets also remain aloft for only a brief period.
- **Mists** range in droplet size from 50 to 100 microns in diameter. They are produced by pumps using medium pressure and specialty nozzles, high-speed mechanical rotors, and atomizers. Mists remain aloft longer than coarse and fine sprays and are subject to dispersal by wind and air currents.
- **Aerosols and fogs** are defined as very fine particles or droplets suspended in air and ranging in size from 0.1 to 50 microns. These may be produced by releasing the pesticide formulation directly into a blast of hot air, as with the thermal aerosol generator, or by mixing them with a liquefied gas which is then released through a small orifice, as with the household "bug bomb." They can also be produced by atomization from specialized nozzles, or by being dispersed from the rim of high-speed rotors.

ADULTICIDING EQUIPMENT

Aerosol Generators

Fogs are dispensed as thermally generated aerosols through combustion exhaust systems, high-pressure steam exhausts, thermal pulse jet systems or as aerosols created by ultra low volume sprayers (cold foggers). Because of their small size, these aerosols generally are not suitable for larviciding, but they are very effective for flying insect control, because the individual droplets do not settle to the ground rapidly. Dispersal of these droplets depends on air currents and other meteorological factors. For example, temperature inversion helps to hold the material below the canopy and consistent light wind (maximum, 8 to 12 mph) serves to propel it through the habitat. Under suitable conditions, such as a temperature inversion with a slight breeze, an effective swath width up to 300 ft or more may be obtained with truck-mounted ground aerosol generators, and much wider swaths with aerial applications.

Specialized generators are used to create aerosol droplets. This is accomplished mechanically with atomizing nozzles, spinning discs, high pressure nozzles or by using heat. Thermal units usually produce fine droplets in the 5 to 10 micron range by vaporizing the carrier portion of the formulation to produce the small droplets. Truck-mounted thermal aerosol generators used in mosquito control programs produce a highly visible insecticide fog that moves across open spaces, killing mosquitoes in flight as air currents move it. Thermal fogging requires a large vehicle to accommodate the volume of oil that is mixed with the insecticide and, because of the sheer volume of droplets that needs to be atomized, the maximum road speed is minimal (10 mph or less). Because of the high cost and possible environmental impact of the petroleum products used in this type of application, the popularity of thermal fogging has waned in recent years.

Ultra-low-volume (ULV) Application

Aerosols of undiluted insecticide are commonly applied at extremely low dosage to control insects of public health importance. Such ULV applications usually range from 0.5 to 3 fl oz per acre atomized into tiny droplets, the majority measuring 5 to 50 microns (from 1/5000 to 1/500 of an inch) in diameter. Unlike thermal fogs, ULV aerosols are barely visible to the onlooker. These very fine droplets do not readily impinge or stick on the surfaces of large objects, but they disperse in air currents and deposit on insects in flight. Drift of the ULV spray cloud is desirable and essential as it enhances the probability of reaching the target insects. Because of the low volumes of insecticide and the relatively wide dispersal of the application, the amount of the pesticide actually depositing on the ground or other surfaces per unit area is actually reduced, compared to larger droplets - resulting in lowered environmental impact.

The ground ULV aerosol machine is relatively small (See Figure 1); its pesticide tank usually has a capacity of 5 to 10 gallons and is mounted on a small vehicle such as a ½ ton pickup truck. They can be either gasoline-powered or electrical. By contrast, the thermal fogger is larger and heavier with an insecticide tank of 25 to 200 gallons or more and is usually mounted on a larger vehicle, such as a 1 to 3 ton truck. ULV applications may be somewhat less effective in heavy vegetation than thermal fogs because of reduced penetration due to the larger droplets. Control of the droplet size is important to ensure proper drift and to prevent car spotting, which can occur with some insecticides due to the corrosive properties of the undiluted active ingredient in larger droplets.

Greater care must be taken in handling the concentrated insecticides used in the ULV method than with the diluted fuel oil formulations used in the thermal foggers. This is due to the possibility of worker exposure during loading or handling prior to atomization. Applicator safety in recent years has been improved by several equipment improvements. For example, the aerosol generator is operated remotely from the cab of the vehicle, flow controllers are available that automatically adjust for vehicle speed, and automatic flow cutoff can be programmed to occur whenever the vehicle stops. Once dispensed, the amount of active ingredient in the aerosol cloud has been determined by EPA to pose little risk to passers-by who might be momentarily exposed. Performance requirements for ULV ground applications against adult mosquitoes are as follows:

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

Aerial ultra-low-volume application

Before aerial application, the applicator and equipment must meet FAA requirements, which may vary depending on whether the aircraft is public or private.

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

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

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

Quick installation systems have been devised for the application of microbial insecticides (*Bti*) in aircraft normally configured for other uses. These systems include a stainless steel cylinder capable of containing several gallons of insecticide, connected by tubing to a rotary nozzle temporarily placed along the wing, and a small CO_2 tank to pressurize the system.

Aircraft spray tanks for holding technical grade insecticides are made of aluminum, stainless steel, or fiberglass. Fiberglass is preferred when applying naled because of the chemical's corrosive nature, and the tubing should be stainless steel or plastic and be able to withstand 2000 psi pressure. Flushing the system after use and filling the lines with nitrogen reduces corrosion problems.

Aerial ULV vector control applications must comply with label rates and directions and are conducted as follows:

- The optimum droplet size is about 25 to 50 microns mmd, depending somewhat on the insecticide characteristics regarding volatility and viscosity. Droplets above 50 microns should be avoided since they waste material, are an inefficient size for killing mosquitoes and do not give adequate coverage. In addition, the hazard to non-target organisms and automobile finishes increases with droplet size, particularly with droplets above 50 - 100 microns.
- Typical applications are conducted at about 150 mph and 100 to 150 ft altitude, with swath widths of 300 to 700 ft. Greater swath widths have been used successfully with multi-engine aircraft flying at higher altitudes; however, droplet size and density per unit area may lose uniformity with increased swath width because the larger droplets fall faster than the smaller droplets - creating an uneven distribution. The greater the percentage of droplets below about 35 microns, the lower the application rate required, the wider the swath can be, the lower the deposition rate on the ground and the less the environmental impact.
- Application success is dependent on ambient wind conditions, temperature at and above ground level and other local meteorological factors, such as temperature inversion.
- Achieving the optimum configuration of application patterns and calibration of ULV spray planes to produce specified droplet spectra and swath widths requires considerable experience and time. Some state and federal agencies and commercial companies have experienced personnel who can assist public agencies with this work. Some of this information is available from the supplier of the technical grade insecticide.

LARVICIDING EQUIPMENT

Hand Sprayers and Dusters are used to apply liquid, granules or pellets to small breeding sites, or to areas that cannot be reached by vehicle. In general, these insecticides are contact or stomach poisons or insect growth regulators.

1. **Compressed air sprayer** -- for applying liquid larvicide such as GB-1111, Agnique, or liquid formulations of Abate, *Bti* or Altosid. The compressed air sprayer is comprised of a tank, air pump, outlet pipe, spray hose, and spray gun consisting of valve, wand and nozzle (See Figure 2). The tank, made of stainless steel, brass, plastic or galvanized steel, forms the body of the sprayer with a capacity usually ranging from 0.5 to 3 gallons and serves as the reservoir for the spray mixture. The space above the spray mixture is pressurized by a hand pump in manually operated units. The pump cylinder ordinarily is fitted to the head of the spray tank with rubber gaskets and has a check valve at the bottom that permits air to be pumped into the sprayer, but prevents air or liquid from being forced back into the pump barrel. The air pressure forces the spray mixture through an outlet pipe to the spray hose.

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

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

2. **Knapsack (backpack) sprayer** -- for applying liquid larvicide. This sprayer (Figure 3), as its name implies, is borne on the back of the operator with shoulder straps so that it can be carried on both shoulders. A simple diaphragm or piston pump and a mechanical agitator are mounted inside the 2 to 5 gal tank and actuated by a lever worked by the operator's right or left hand. The insecticide is under liquid pressure during each stroke of the pump. Knapsack sprayers are used chiefly in areas that are difficult to reach, such as for mosquito larviciding in very swampy areas where it is difficult to pump a compressed air sprayer. Most have a special hand-operated lever to prime a pump to pressurize the sprayer. Depending on the model, pressures up to

150 psi can be generated, although working pressure on most is usually between 50 and 75 psi. Adjustable cone or flood jet nozzles are usually standard equipment on these sprayers.

3. **Granular applicators** are designed to apply coarse, dry particles that are uniform in size to soil or water (as a pre-larvicide or larvicide, respectively). Two examples of granule applicators are a cyclone spreader and a sling, or horn, seeder (Figures 4 and 5). The cyclone spreader is a cylinder with an adjustable slot in the base, through which granules fall onto a rotating disk. They are manually operated and the granules are dispersed by centrifugal force generated by gears that are activated by turning the crank handle. The sling seeder is made from a canvas bag with a tapered, telescoping wand at the lower front corner of the bag. The bat is slung over the operator's shoulder and granules are released by swinging the wand in a horizontal motion. The application rates can be adjusted with each of these devices by changing the openings through which the granules pass or the speed that the operator traverses.

Power Sprayers and Dusters

1. **Hydraulic power sprayer** -- vehicle mounted unit for applying liquid larvicides to large areas or areas that can be accessed by vehicle (Figure 6). The spray liquid is pressurized by means of a power-driven hydraulic pump fitted with suitable regulators to maintain the desired pressure – from 20 to 800 psi. The spray pattern is determined by the pressure and the type of nozzle used, varying from a solid stream to a fine mist. Power sprayers usually have a tank of 50 to 600 gallon capacity with a rotating agitator to keep insecticides in suspension. A gasoline motor or power take-off operates the piston type hydraulic pump. The power sprayers most often used in mosquito control operations are usually less than 150 gallon capacity, mounted on skids in the bed of a ¾ to 1½ ton truck, or used as smaller backpack units. These sprayers deliver a maximum of 1 to 7 gallons of spray per minute and are equipped with pressure regulators to maintain the recommended pressure.

2. **Small portable power duster** -- a backpack unit with a gasoline engine which operates a radial fan to discharge insecticide (Figure 7). Some models come with different attachments to accomodate granules, dusts or liquids.

3. **Large truck-mounted power duster-mister** – known as the Buffalo Turbine, these were used to apply granular larvicides to large areas and in the past were used to apply dust for adulticiding. These are rarely seen in mosquito control programs today.

4. **Power granular cannon** (e.g., "Arro-Gun")-- an attachment for ULV units that dispenses granular or pelletized larvicides for distances up to 90 ft. A wide variety of granules, pellets and even briquets can be rapidly blown out through the cannon's barrel. A separate hopper and feeder lines are provided. This attachment can also be used to dispense sand and ice-melting granules for snow removal operations.

WINTERIZATION OF SPRAY EQUIPMENT

When the mosquito season has ended in the fall, a little effort spent on your spray equipment may save money and will ensure that your equipment will be ready when you need it the following spring. The expense of most of your equipment makes it wasteful not to take care of it, and most local governments that fund mosquito control programs would not appreciate having to buy new equipment each spring to replace that damaged by neglect in the fall.

The following suggestions are made for the winterization of equipment:

Hand Sprayers

1. Rinse sprayers thoroughly and pump a gallon or more of clean water through the unit.

2. Disassemble each sprayer completely and place the small metal parts in kerosene to sit before cleaning them with a small bottle brush.

3. Soak the nozzles, wands, and tanks in a sodium triphosphate solution; clean them with a scrubbing brush and rinse them thoroughly with water.

4. Replace worn out gaskets and other parts as necessary.

5. Reassemble the sprayer and pump through it two complete changes of water containing one cup of vinegar per gallon of water.

6. Pump a final complete change of clean water through the sprayer; let it dry; store in a clean, protected place for future use.

Power Equipment

Follow manufacturer's instructions for cleaning and storage, if provided, OR:

1. Partially fill the tank with water and run the equipment until clear water emerges from the nozzles. Completely drain all water from the lines, pump and tank, then run antifreeze through the system in order to prevent freezing. Water left in the sprayer pump can cause expensive damage after the first freeze, so don't postpone cleaning and preparing your power sprayer. The pump should also be greased properly.

2. Clean all equipment thoroughly and check for worn parts and leaks. Order any replacement parts NOW so that the unit will be repaired and ready to operate next spring. Disassemble nozzles and clean them as instructed above. Line strainers should be checked and cleaned (replace if necessary).

3. If possible store all equipment indoors in a heated area. If this is not possible, remove the hoses and clean and store them indoors coiled neatly in a pail or straightened out on a shelf. Avoid sharp kinks when storing hoses. If equipment must be stored outdoors,

cover it securely with a good tarp to protect it from our New Mexico elements, especially dust.

ULV Adulticiding Units (Adapted from *Ohio Vector News*)

- Complete steam cleaning
- Engine tune-up
  - New plugs
  - New points
  - New condenser
  - Carburetor adjustment
- Clean filters
  - Clean or replace blower air filter element
  - Clean or replace insecticide filter element
  - Clean or replace Briggs air filter element
  - Clean or replace gas filter element
- Grease nozzle elbow unions
- Flush out complete insecticide system
- Check all hoses and replace if necessary
- Check all belts (if any) and replace if necessary
- Check all connectors and o-rings and replace if necessary
- Check-out electrical system
- Battery service
- Grease bearings
- Check for any broken welds and repair as necessary
- Check spreader ring and ULV nozzle (if nylon, replace)
- Check for missing bolts and replace
- Test run the unit
- Winterizing blower unit and engine
  - Change Briggs engine oil
  - Change blower oil
  - Remove filter and pour in 1/2 quart engine oil
  - Turn blower by hand 10-12 times -- replace filter
  - Remove spark plug from Briggs engine
  - Pour 1/2 pint engine oil into engine -- replace plug
  - Turn blower head down
  - Cover all with tarp
- For units with pumping systems
  - Transmission fluid (automobile) should be drawn up into the pumping unit
  - To do this simply place the intake line in a container of transmission fluid and turn on pump
  - Not necessary for pressurized systems using flow meter
- Store unit indoors or cover entire unit with good tarp and secure ULV in safe place

"TAKE CARE OF YOUR EQUIPMENT AND IT WILL TAKE CARE OF YOU!"

HAND SPRAYER CALIBRATION

From an article in *VectorBytes* by Ed Meehan (June 2000)

1. Select a practice area such as a hard, parking lot surface. Mark an area 4 feet wide and 50 feet long. Ed suggests a flat fan spray tip rather than a cone type, to make it easier to define the area being sprayed.

2. Fill your sprayer with water.

3. Maintain a constant pressure.

4. Hold the tip approximately 14 inches above the surface.

5. Walk a slow and steady pace that gives even coverage. While spraying look back and observe where you have sprayed. If it is drying in patches (not even) then you are not applying the water evenly. Once you learn to spray evenly, determine how long a path is sprayed in 15 seconds.

6. Determine the amount of water sprayed (in ounces) in 15 seconds by catching the spray in a container. Note: Installing an inexpensive pressure regulator in the sprayer hose will greatly increase your accuracy. Also, taking a full 60 second sample and dividing by four to get the 15 second amount will be a lot more accurate than just one 15 second sample.

7. Next, determine the amount (in ounces) that your sprayer tank will hold. One gallon = 128 ounces, so a 1 ½ gallon sprayer will hold 192 ounces. A 3 gallon sprayer will hold 384 ounces.

8. Knowing the two items above, you can calculate how much area your full sprayer should cover (See example below).

$$\frac{\text{(area sprayed in 15 seconds)} \times \text{(sprayer capacity in ounces)}}{\text{(amount sprayed into a container in 15 seconds)}} = \text{area (square ft) covered}$$

Example

1. Area sprayed: In 15 seconds you traveled 35 feet, while spraying a path 4 ft. wide. 35 x 4 = 140 square feet covered
2. Sprayer capacity: You had a 1 ½ gallon sprayer so your capacity is 192 ounces.
3. Amount sprayed: In 15 seconds you measured 10 ounces in your container.

$$\frac{140 \times 192}{10} = \frac{26{,}880 \text{ sq. ft}}{10} = 2{,}688 \text{ square feet that your full sprayer should cover}$$

Check Yourself

Now go back out on a hard surface with a sprayer full of water. Mark off an area that matches your full sprayer capacity, in this case, 2,688 square feet. Using a swath width of 4 ft, mark off a length of 168 feet. Start spraying and at the end of the 168 feet, move over 4 ft and start back – making 4 swatches in total (4 ft x 168 ft x 4 = 2,688 square feet). If you are applying correctly, your sprayer should go empty, just as you pass the finish line on your last pass.

You can use more or less swaths to total the area needed (and different nozzle tips will have different swath widths and you will need to adjust for that in all the calculations). Obviously, each person will have to calibrate themselves, as well as the sprayer, because we all have different walking speeds.

Now – correct application rate

In our example you have calculated that your 1 ½ gallon sprayer will cover 2,688 square feet. This can be converted to gallons per acre for ease of determining the correct application rate.

$$\frac{\text{(capacity of sprayer in gallons)} \times \text{43,560 square feet/acre}}{\text{(area that full sprayer will cover)}} = \text{gallons/acre}$$

In our example:

$$\frac{1.5 \times 43{,}560}{2{,}688} = 24.3 \text{ gallons/acre}$$

Let's say the product you are using is Vector Lex WDG – water dispersible granules. The application rate is 8 – 24 ounces per acre. To calculate how much of the product you put into your sprayer before diluting with water:

$$\frac{\text{(application rate in oz/acre)} \times \text{(capacity of sprayer in gallons)}}{\text{sprayer coverage in gallons/acre}} = \text{amount of product in ounces}$$

Using an application rate of 16 ounces per acre:

$$\frac{16 \times 1.5}{24.3} = 0.99$$ ounces, or about one ounce of product in a full sprayer of water

As you can see this is not very much product. But remember, the area that your sprayer covers (in our example) is only 0.06 of an acre! So, 0.06 acre multiplied by 16 ounces per acre equals, you guessed it, 0.99 ounces!

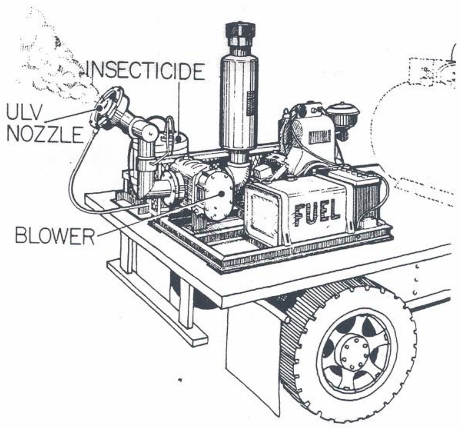


Figure 1. Truck-Mounted Ultra-Low-Volume Aerosol Generator

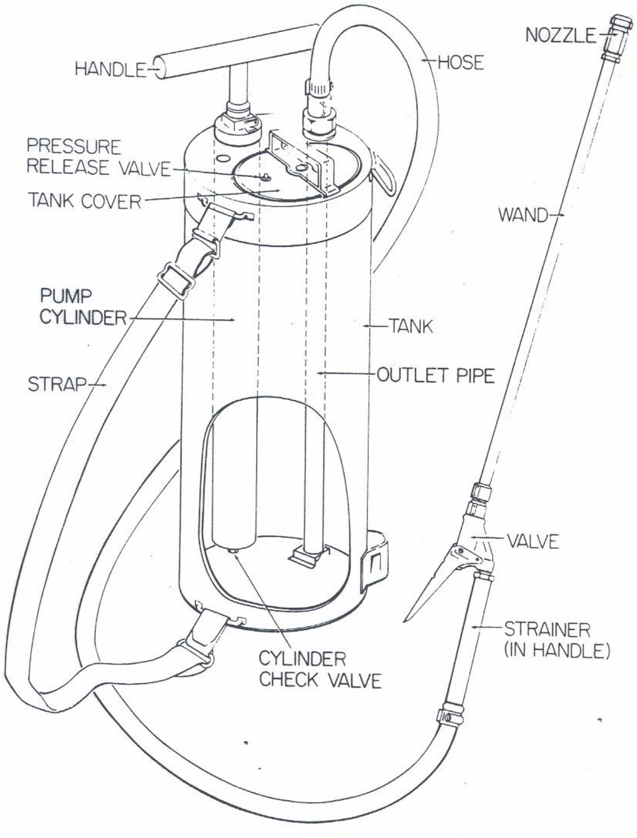


Figure 2. Compressed Air Sprayer

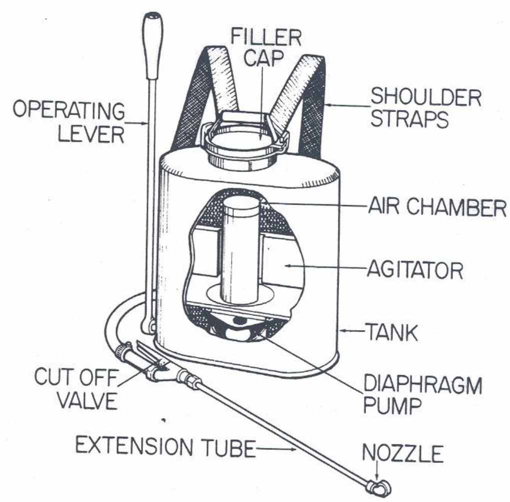


Figure 3. Knapsack Sprayer

Figure 4. Cyclone Seeder

Figure 5. Sling Seeder

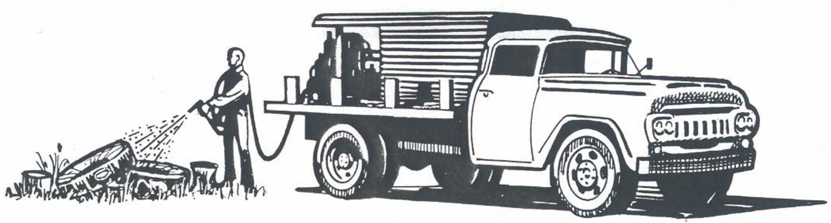
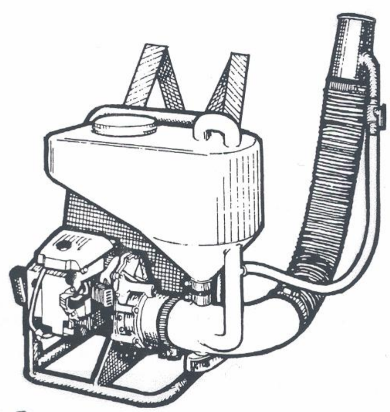


Figure 6.. Hydraulic Sprayer



. Figure 7. Small Portable Power Duster-Mister

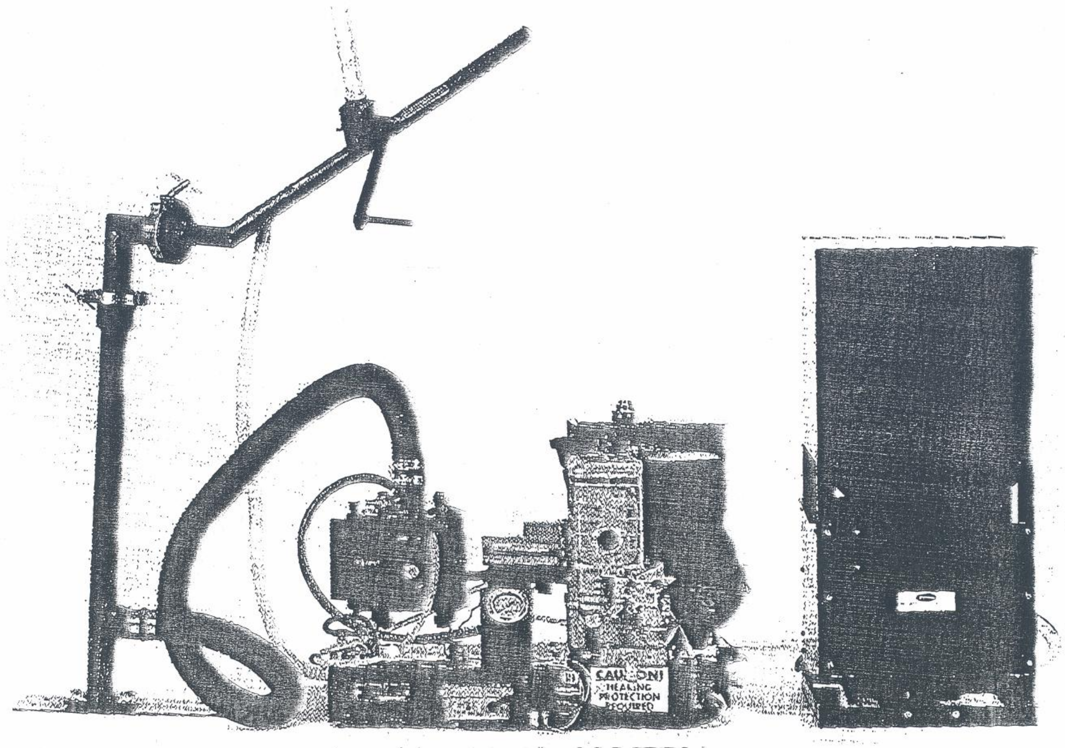


Figure 8. Power Granular Cannon

Backpack Power Duster

Compressed Air Sprayer

Truck Mounted
Electric ULV