Chapter 8

APPLICATION EQUIPMENT

8-1. General Information. The effectiveness of a herbicide depends largely on how well it is applied, and this, in turn, depends on the operator and the equipment.

a. Various types of equipment are available for applying herbicides (1) wet in sprays or mists, (2) dry, in dusts, pellets, or granules, and (3) as fumigants. An ideal applicator would distribute the herbicide uniformly on foliage, on or in the soil, or in water.

b. Spraying is the most common application method, and may be used for all herbicides except for some fumigants and aquatic treatments. Spraying not only permits reasonably uniform application, but a spray can be directed at a specific area. Sprays may be applied from sprinkler cans, hand pumps, and compressed-air and power sprayers.

c. The backpack sprayer is the most popular type of hand-operated sprayer. Many backpack sprayers use compressed air or gas to force the liquid out of the tank. Others have a pump with a hand-lever that is operated with one hand while the spray wand is held with the other. Hand-operated sprayers usually have a tank capacity of 3 or 4 gallons, and are most useful for spraying small, scattered weed patches and areas that are inaccessible to power equipment. Backpack sprayers are generally not appropriate for very toxic sprays.

d. Power-driven sprayers range from small, wheel-mounted rigs that are useful in turf and gardens, to large field sprayers. Field sprayers may be trailer-mounted, truck- or tractor-mounted, or self-propelled.

e. Sprayers are classified as low-volume or high-volume, depending on the amount of liquid (carrier and herbicide) they normally apply per unit area. Spray volumes range from 0.1 gallon to several hundred gallons per acre. Most weed sprayers are of the low-volume type (40 gallons or less per acre). High-volume sprayers are usually used where vegetation must be saturated.

f. Any water supply line used to fill sprayer tanks should have a backflow prevention device to prevent contamination of the facility water system.

8-2. Ground Spraying Equipment. Most sprayers consist of a container or tank to hold the spray liquid, some type of nozzle or nozzles to direct the spray, and a pump to force the spray through the nozzles. They usually have a pressure regulator, pressure gauge, shutoff valve, strainers or filters, and chemical-resistant connecting hoses.

a. Tanks and Agitators.

(1) The trend in sprayers is toward using corrosion-resistant materials throughout the system. Mild steel rusts and flakes off, causing delays and poor weed control because of frequent nozzle-clogging. Three materials currently used for spray tanks are stainless steel, aluminum, and fiberglass-reinforced plastic (FRP). Type 304 stainless steel and FRP resist corrosion by almost all types of agricultural chemicals. Aluminum is vulnerable to attack by some herbicide solutions.

(2) Agitation is always desirable to ensure homogeneity of the spray liquid, even if totally soluble materials are used. The two types of agitation are mechanical and hydraulic.

(a) Mechanical agitation is achieved by a series of paddles on a shaft running horizontally through the tank, or by means of a propeller on one end of the tank. The paddles or propeller are power-driven at low speed. Mechanical agitation is generally used for emulsions with a high percentage of oil and for wettable powders.

(b) Hydraulic agitation is accomplished by routing some of the pressurized spray liquid back into the tank. The number, size, and location of the orifices through which the liquid is routed back into the tank depends on the size and shape of the tank. Hydraulic agitation is most often used for readily soluble or self-emulsifying materials.

(3) All tanks should have a large filler opening to facilitate cleaning between uses of different chemicals.

b. Nozzles and Tips:

(1) Nozzles and nozzle tips are made of brass, aluminum, stainless steel, nylon, plastics, and rubber. For chemicals that are corrosive or abrasive, materials harder than brass should be used. Most wettable powders are abrasive, and AMS, for example, is corrosive to brass.

(2) The nozzle tip converts the sprary liquid into droplets and is thus the most important component of the sprayer. Nozzle tips should be selected to produce the spray pattern best suited to the particular application. The three basic spray patterns are fan-shaped, cone-shaped, and flooding.

(a) Nozzles producing a flat, fan-shaped spray are the most popular for weed control. They produce an even distribution across the width of the spray. When evenly spaced on spray booms, they distribute the herbicide across the boom swath. Sometimes they are designed to produce a lighter spray at the edges of the spray pattern, resulting in more uniform application where nozzle patterns overlap within the boom swath.

(b) Hollow-cone nozzles produce a cone-shaped spray, with the heaviest droplet distribution on the outer edges of the pattern. Coverage is less uniform than with the flat-fan nozzle, but cone nozzles operate more satisfactorily at low application rates of about 2 to 3 gallons per acre.

(c) Flooding nozzles deliver coarse droplets of spray under low pressure, thus minimizing drift. They produce a wide-angle fan pattern. Because the nozzle orifices are large, clogging is also reduced.

(3) There are a number of nozzles for special situations. The boomless or cluster nozzle, for example, is often used on rights-of-way where obstructions would interfere with the operation of a spray boom, and in grasslands where scattered trees would interfere with a boom. It provides a rather varible distribution of spray because its wide range of droplet sizes are affected differentially by wind. It is particularly useful on rough terrain that would be hazardous to spray booms.

(4) The pressure in the system determines the rate of flow through the nozzle orifice. Increasing or decreasing the pressure affects the size of spray droplets. Increasing the pressure produces a finer spray; to increase volume it is more effective to increase the size of the orifice. The distance that the spray is projected depends primarily on the pressure being delivered by the pump.

c. **Types of Pumps.** The four most common types of pumps are piston, centrifugal, gear, and impeller.

(1) Piston pumps are probably the most versatile, and before 1945 they were used on nearly all sprayers. They can deliver a wide range of pressures, from 40 to 1,000 lb/in^2 making them useful for chemicals other than herbicides. They are easily repaired, are resistant to wear by abrasive materials such as wettable powders, and have long service lives. Each stroke of the pump delivers a given amount of spray liquid, and, therefore, the output of the pump is directly proportional to its speed. Disadvantages of piston pumps are their low delivery rate and high initial cost, but their long service life usually offsets the latter. The low delivery rate, however, means that mechanical agitation is necessary if wettable powders are used.

(2) Centrifugal or turbine pumps develop pressure through centrifugal force created by rapidly rotating blades, fins, or disks. They are inexpensive and handle abrasive materials well. They provide a high delivery rate with enough excess flow to provide hydraulic agitation in the spray tank. To maintain adequate pressure, however, centrifugal pumps must be operated at higher speed than other pumps. They generally are not self-priming, and must be placed below the spray tank to ensure gravity flow to the pump.

(3) Gear pumps develop both vacuum and pressure through meshing gear teeth. They may be used advantageously for oil emulsions and other nonabrasive materials, but have a limited life under adverse usage, such as with wettable powders. Because they are cheap, gear pumps are usually replaced rather than repaired. Their delivery rate varies with size, but is usually adequate for hydraulic agitation.

(4) Impeller pumps have a rotor set to one side within the pump housing. The rotor has flexible rubber vanes or rollers that maintain contact with the wall of the housing. The space between the rotor and pump housing expands for half of every revolution and contracts for the other half, thus creating an alternation of vacuum and pressure. In recent years, the roller-type of impeller pump has become extremely popular. The rollers are made of nylon or rubber, and work best with oil emulsions and nonabrasive materials. Rubber rollers are the most satisfactory with abrasive materials. Worn parts can be replaced in most instances. Impeller pumps are moderately priced and provide sufficient volume for most applications.

d. **Pressure Regulators and Control Valves:**

(1) Pressure regulators, or relief valves, are used to maintain a relatively constant pressure at the nozzle. It generally consists of a ball that is held against an orifice by a spring that can be screw-adjusted to vary the pressure. Variations include a double-spring type and a combination of spring and diaphragm. Excess liquid is released back into the spray tank through a bypass port. A pressure gauge is usually placed on the outlet side of the regulator, between the regula-

tor and the spray boom, to indicate nozzle pressure.

(2) Two types of control valves are in general use. A quick-opening valve is used to turn the flow on or off to all nozzles, and selector valves control the flow to individual sections of a spray boom. Selection valves enable an operator to spray from any or all sections of a boom.

e. Hoses and Strainers:

(1) Hoses on sprayers should be of a material that will withstand the chemicals used, particularly petroleum solvents. Synthetic rubber and plastic are most common. Heavy-walled hoses or metal pipe are used for extremely high pressures.

(2) Strainers or filters are used between the tank and the pump as line filters and behind each nozzle orifice. Some have built-in valves to prevent nozzle dripping. In filling the tank, a coarse strainer should be used to filter the spray liquid. Wettable powders rarely pass through screens finer than 50 mesh. Screens for emulsions should be about 100 mesh.

f. Boomless Sprayers. Boomless sprayers with cluster nozzles are well adapted for spraying roadsides, ditchbanks, rights-of-way, fence rows, and areas where trees would interfere with the operation of booms.

(1) Boomless sprayers are less expensive, simpler to operate, and have less nozzle trouble than boom sprayers. They can pass between trees and shrubs, be maneuvered close to obstacles, and are practical for rough ground. They spray a 20- to 30-foot swath with large volumes that provide moderately good coverage.

(2) The equipment can be mounted on a four-wheel-drive vehicle or caterpillar-type tractor. The chief disadvantage of boomless sprayers is that the spray swath is greatly affected by wind. They should not be used when the wind may cause drift to nearby sensitive vegetation.

g. Boom Sprayers:

(1) Boom sprayers are adapted for large areas where completed coverage is necessary, and for turf areas adjacent to roads where applications can be made from tractor- or truck-side-mounted booms. These units have spray booms with evenly spaced nozzles.

(2) For roadside or ditchbank spraying, remotely controlled truck-mounted side-arm booms are advantageous. The boom may have nozzles evenly spaced along each segment of the arm, and may terminate in a boomless-type spray nozzle. It may be horizontal for roadside or ditch spraying, or vertical to spray above trees, shrubs, and tall weeds. Each boom segment is hydraulically controlled by an operator sitting next to the driver.

(3) For roadside spraying, two or more nozzles are grouped together and mounted on an arm that reaches over mailboxes, highway signs, and similar obstacles. A truck-mounted boom designed to spray under guard rails reaches over the rail and sprays from the outside toward the pavement.

h. Mist Blowers. Mist blowers disperse highly concentrated sprays in a finely atomized form at low volumes per acre. The herbicide is carried principally in an airstream instead of a liquid. These sprayers are free of boom and nozzle problems, require minimal amounts of water, cover vegetation rapidly, can be used for areas that are inaccessible to other power equipment, and are cheaper than conventional hydraulically powered equipment. They are very useful for spraying under fences, around stone piles, along roadsides, in drainage ditches, and under power-lines. The use of mist blowers for herbicides, however, is limited by the serious hazard of drift. Mist blowers in 5 to 12 horsepower sizes are useful for brush spraying where drift is not a problem. A 2-horsepower knapsack mist blower is useful for brush up to 30 feet tall, and for spot spraying.

i. Wipe-on Equipment. This equipment is a means of using nonselective herbicides with no drift hazard and with almost no soil residues. It is especially useful for controlling taller weeds and brush sprouts in low-growing grass and other ground covers.

(1) The rope wick applicator consists of several loosely woven wicks, the ends of which are inserted into holes in a large plastic pipe. The pipe contains the herbicide solution. The applicator is adjusted to a height just above the lower-growing, desirable vegetation, and kills only the taller plants that are wiped by the rope wick as it goes through the field. There are variations for specialized uses, such as around shrubs, small trees, and other obstructions. One such is the hand-held "hockey stick" applicator which has special padding fashioned for the curved lower end of a stick. This is moistened with herbicide through a plastic tube having a hand-operated valve. Such items are available commercially.

(2) The rolling carpet applicator is used in the same way as the rope wick applicator. It consists of a horizontal rotating, carpet-covered

roller that is continuously moistened by herbicide solution. The roller may be a foot or more in diameter.

j. Controlling Drift. No discussion of spray application would be complete without mentioning drift problems. Drift can result in considerable damage to susceptible plants outside the treatment area, and can lead to costly litigation.

(1) Drift is a function of droplet size and atmospheric conditions. Droplets 10 micrometers in diameter can drift up to 1 mile when released at a height of 10 feet in a 3 mi/h wind. The small the droplets, the more likely they are to be carried by air movement. Larger drops drift less, but they do not provide as uniform plant coverage.

(2) Research indicates that droplet size is affected by operating pressure; nozzle design; nozzle orientation; properties of the spray liquid; and atmospheric conditions.

(3) Few nozzles used for spraying will produce uniform droplets large enough to minimize drift, yet small enough to provide even coverage. A spray nozzle designed to produce a mean droplet diameter of 150 micrometers also produces many tiny droplets ranging from 1 to 2 micrometers and coarser droplets ranging from 300 to 400 micrometers. Efforts have been made to formulate sprays so that the drops produced by a particular type of nozzle will be large enough to reduce drift. These efforts have been only partly successful, because small drops commonly form from fluid pulled from the surface of the larger droplets. Also, evaporation of spray droplets decreases their size as they fall.

(4) The spray operator can use various measures to control droplet size. Water-soluble thickening agents are often added to spray liquids to increase average droplet size. A water-imbibing polymer is sometimes used to create particulated gel spray. The smallest droplet of such a spray is predetermined by the size of the polymer particle. The use of an invert-emulsion spray (water droplets suspended in a continuous oil phase) that has high viscosity will reduce drift. Decreasing the delivery pressure in spray systems will produce large droplets, and relatively high-volume "dribble bars" have been designed that operate under minimum pressure. Also, a vibrating nozzle designed to provide uniform droplet distribution from low-pressure streams offers promise for relatively drift-free applications.

8-3. Granule Application Equipment. A wide variety of applicators are used to broadcast granular herbicides. They are generally refined fertilizer applicators or seeders, and some simultaneously plant seeds, distribute fertilizers, and apply herbicides. Some include incorporation equipment. The major components are a band distributor or spatter plate that distributes the granules laterally and uniformly over the desired bandwidth, and an easily calibrated device that meters the granules.

a. Meters and Nozzles:

(1) Metering devices have reached a high level of precision, and several different types are used. Among these are a variable orifice with a rotor-bar agitator between the hopper and the orifice, a variable orifice with a rubber-flanged impeller, a variable orifice between the hopper and an oscillation plate, and a fixed orifice with a variable-speed screw-conveyor auger.

(2) Five types of nozzles or distributors are available for spreading granules. Distribution patterns in the field are usually more uneven than laboratory patterns, because some granules move laterally after hitting the ground. A chain drag may reduce the lateral movement of granules by roughening that convex surface left by press wheels. Studies have shown that down-the-row distribution is more uniform than across-the-row distribution.

(3) Wind speeds of 10 mi/h or more may cause considerable shifting of the distribution pattern. Special wind guards have been developed to prevent lateral movement of the granules under windy conditions.

b. Soil Incorporation Equipment:

(1) Granular herbicides are often mechanically incorporated into the soil to reduce their loss and to bring them into contact with germinating weed seedlings. Incorporation is needed if thiocarbamates or other volatile herbicides are applied. The incorporation method varies with the chemical and physical nature of the herbicide, the soil conditions and properties, the method of water application, and the crops and weeds involved.

(2) Attempts have been made to incorporate herbicides with almost every implement used to till the soil. Under proper conditions, desired results can be obtained with harrows, disks, subsurface blades, bed shapers, and power-driven rotary-tillers.

(3) With overhead irrigation, shall incorporation with a harrow or rotary-tiller may suffice to prevent the loss of volatile herbicides until water carries them deeper into the soil. With furrow irrigation, deeper and more thorough

mechanical incorporation is required. Disks or power-driven rotary-tillers usually provide the best results. Subsurface blades have been used under special conditions, but are still experimental.

8-4. Aquatic Application Equipment. Aquatic herbicide applicators may be boat- or barge-mounted blowers, sprayers, booms with injection systems, or granule spreaders having essentially the same features as ground equipment. Liquid aquatic herbicides also can be applied with a venturi pump/injector powered by propwash. Slow-release granular herbicides can be applied by a Buffalo turbine or by dragging them in a porous bag behind a boat. Aerial applications are sometimes made for general control of aquatic weeds.

8-5. Aerial Spraying Equipment. Aerial application equipment has improved steadily with the increased use of chemical sprays in all areas of agriculture. The use of appropriate equipment, its proper adjustment, and skill in carrying out the spraying operation are vital for satisfactory results. Because most aerial spraying will be done by specialists such as the Air Force Aerial Spray Branch (356 TAS/Aerial Spray, Rickenbacker ANGB OH 43217-5008) or contractors, this description is brief.

a. The components of airborne sprayers are much the same as those of ground equipment, and calibration methods are similar (see chapter 9). The application speeds of fixed wing aircraft, however, usually range from 90 to 200 mi/h, in contrast to ground sprayer speeds of 3 to 5 mi/h.

b. Spray pumps on aircraft are driven by a V-belt drive from the main engine, a small direct-connected propeller, an electric motor, or some other power source. Centrifugal pumps are usually used because of the high delivery rates required, and agitation is usually by hydraulic bypass from the pump.

c. Booms are generally shorter than the aircraft's wingspan so as to reduce the effects of the wingtip vortices. Although spray booms extending beyond the wingtips are used in applying some insecticides, they are not recommended for the precision swaths required for herbicide treatments. Nozzles should not be extended more than within 2 or 3 feet of the wingtips, because upward movement of air at the wingtip vortices results in considerable loss of spray to upper air currents and creates a serious drift hazard.

d. Some distortion of the swath by the slipstream occurs with all aircraft. This is especially true with single-engine aircraft, and the larger the aircraft engine, the greater is the amount of distortion. Nozzles that are evenly spaced on the boom do not provide an even spray pattern with some aircraft. Instead, they result in an uneven and streaked swath. To compensate for these effects, additional nozzles (or nozzles with larger tips) should be placed at certain points along the boom, as determined experimentally.

e. The nozzles are usually designed and placed to control droplet size. Too many droplets below 100 micrometers in diameter increases the risk of drift. High-velocity air passing over the face of a standard nozzle has more influence on droplet size than does orifice size or pressure. Droplet size can be altered by changing the angle or position of the nozzle in relation to the airstream. For herbicide application, nozzles should always be pointed away from the direction of flight.

f. Because aerial sprays are released from a greater height than ground sprays, drift hazards are an even greater problem. Also, the aircraft creates turbulence, propwash, and wingtip vortices, all of which increase the potential for drift to nontarget areas. Aerial spraying should always be carried out when the air is relatively still. Drift retardant additives are used to minimize the risk of drift under less than optimum spraying conditions.

g. Precise flagging is necessary to guarantee proper swaths during field spraying. Flagmen should always be equipped with an accurate measuring device for checking swath spacing. Flagmen should move upwind of the spraying to minimize exposure to the spray.

h. Ground-to-air communications enhance aerial application by allowing adjustments of spraying altitude and swath spacing, reporting of nozzle malfunctions, etc.

8-6. Fumigation Equipment:

a. Increased use of soil fumigants to control weeds, plant-feeding nematodes, and soil-inhabiting insects has resulted in numerous modifications of fumigant injectors to meet special requirements. Fumigant injectors may be hand- or power-operated and can be thought of as underground sprayers.

b. Fumigant injectors have a reservoir, a pump, and a metering device to control the delivery rate. The pump acts as the metering device in hand-operated injectors. Power injectors apply a continuous stream of fumigant in the bottom of the plow furrow or behind the shanks of a chisel cultivator. The delivery rate is determined by line pressure and the size of the orifice. Both the delivery rate and the speed of the tractor determine how many gallons of fumigant are applied per acre.

c. Various means may be used to prevent too rapid a loss of toxic vapors from the soil. Some power-operated fumigant injectors are equipped with devices that tamp and pack the soil. One such device consists of a float and a roller that simultaneously smooth and pack soil over the treated area. Other equipment has been designed to lay plastic sheeting behind the injector to cover the treated area.

d. For small area, special devices can be used to release fumigants under plastic covers that are sealed with soil at the edges. One such device punctures a 1-pound can of methyl bromide with a metal tube, the other end of which is connected to a plastic hose that extends under the edge of the plastic cover. Methyl bromide, being a liquid under pressure in the can, is discharged through the hose under the cover. Another device holds a can of methyl bromide in an upright position on top of a sharpened spike. After lightly placing a can of methyl bromide in the holder and placing both under the sealed cover, the operator releases the methyl bromide by applying enough pressure on the top of the can to puncture it.

8-7. Cleaning Equipment and Preparing It for Storage:

a. All spraying equipment should be cleaned after each use. If the chemical is water soluble, a thorough flushing and rinsing with water is sufficient. Herbicides such as 2,4-D, picloram, and dicamba, however, are very difficult to clean from equipment. In such cases, remove and clean the nozzles and then clean the rest of the equipment with an ammonia or charcoal rinse:

(1) Remove nozzles and scrub with kerosene.

(2) Ammonia rinse:

(a) Add 8 to 16 ounces of nonsudsing detergent to 30 to 40 gallons of water, run through the pump and bypass for 5 minutes, and then run out through the boom.

(b) Partly fill the tank with a solution of 1 to 2 percent household ammonia (1 to 2 quarts of household ammonia in 25 gallons of water, or 2 teaspoons per quart of water).

(c) Leave this solution in the sprayer (including hoses and boom) overnight.

(d) Rinse thoroughly with clean water.

(3) Charcoal rinse:

(a) Use at least one-third of a tank of water. For each 10 gallons of water, add 4 ounces of 100-mesh activated charcoal and 2 to 4 ounces of laundry detergent. Agitate this mixture vigorously to distribute the charcoal through the water.

(b) Wash the equipment for 2 minutes by swirling the liquid around so that it reaches all parts of the tank. Pump some of the liquid through the hoses and nozzles.

(c) Drain the tank and rinse the equipment with clean water.

b. Dispose of excess herbicide mixtures and rinseate according to Armed Forces Pest Management Board Technical Information Memorandum 21, Pesticide Disposal.

c. Preparing Equipment for Storage:

(1) Scrub the sprayer with a stiff-bristle brush. Coat all iron parts that were exposed to the chemical with a rust inhibitor or light oil. Remove all nozzles and disassemble, clean, and store them in light oil. (Before using the sprayer the next year, wash the nozzle(s) in a degreaser or high flash-point solvent to remove the oil).

(2) Fill the pump with a rust preventive.

(3) Remove the caps from the ends of booms, and stand the booms on end to remove sediment. Remove, clean, and reassemble all filters.

(4) If the sprayer is powered by a gasoline engine, drain the fuel tank and carburetor and pour a tablespoon of engine oil into each spark plug hole. Turn the engine over by hand to distribute oil on the cylinder walls.

(5) If the sprayer is to be stored outside, remove all rubber hoses and keep them in a cool dark place.

(6) Thoroughly clean dusters and spreaders before storage.