Application Equipment
Learning Objectives

After you complete your study of this unit, you should be able to:

- Select the right types of sprayers for various kinds of pest control situations.
- Recognize advantages and disadvantages of commonly used sprayer types.
- Show that you know the common types of sprayer pumps and some of their features.
- Explain the use of strainers in a sprayer system.
- Identify desirable features of common parts of a sprayer system — tanks, hoses, pressure gauges and regulators, and valves.
- Name the three primary types of agitation used in sprayer systems and identify the formulations for which each is suitable.
- Identify the parts of a nozzle.
- Select the right nozzle pattern for various application situations.
- Explain how to clear a clogged nozzle.
- Explain some advantages and limitations of aerosol generators and foggers.
- Show that you know the important features of the basic types of soil fumigation equipment.
- Show that you know the basic features of equipment that applies dusts and granules.
- Show that you know the basic features of application equipment used in animal pest control.
- Identify the uses for some types of specialized application equipment.

Terms To Know

Abrasive — Capable of wearing away or grinding down another object.
Agitation — The process of stirring or mixing.
Calibrate — Measure and adjust the amount of pesticide the application equipment will release per unit of area. Concentrate — Pesticide having a high percentage of active ingredient; occasionally applied full-strength, but usually diluted before application. Corrosion — Process of being worn away gradually by chemical action. Diluent — Anything used to dilute a pesticide. Dilute pesticide — A pesticide that is not concentrated; one that does not have a high percentage of active ingredient. Drift — Pesticide being carried away from the release site by air movement. Emulsifiable concentrate — A pesticide formulation that usually contains a liquid active ingredient, one or more petroleum-based solvents, and an agent that allows the formulation to be mixed with water to form an emulsion (droplets of one liquid dispersed in another liquid). Foliage — Primarily the leaves; may include stems of a plant. Formulation — Pesticide product as sold, usually a mixture of active and inert ingredients. Fumigant — Pesticide that is a vapor or gas or that forms a vapor or gas when applied and whose pesticidal action occurs in the gaseous state. gpm — Gallons per minute. Hydraulic agitation — Stirring or mixing provided by the high-pressure flow of surplus spray material from the pump. Hydraulic — Operated by the pressure created by forcing liquid through a narrow opening. Mechanical agitation — Stirring or mixing done by rotating paddles or propellers in the sprayer tank. Mild steel — Steel that contains a very low percentage of carbon; also called "soft steel." Nontarget — Any site or organism other than the site or pest at which the pesticide is being directed.
Personal protective equipment — Devices and clothing worn to protect the human body from contact with pesticides or pesticide residues. psi — Pounds per square inch. Soluble powder — Dry pesticide formulation that forms a true solution when mixed with water. Solvent — A liquid, such as water, kerosene, xylene, or alcohol, that will dissolve a pesticide (or other substance) to form a solution. Suspension — A substance that consists of undissolved particles mixed throughout a liquid. Target — The site or pest toward which control measures are being directed. Volatile — Evaporating rapidly; turning easily into a gas or vapor. Wetable powder — A dry pesticide formulation, usually mixed with water for application. Does not dissolve in water, but forms a suspension.
Application Equipment

The pesticide application equipment you use is important to the success of your pest control job. First, you must select the right kind of application equipment; then you must use it correctly and take good care of it.

This unit provides an overview of some things you should know about choosing, using, and caring for equipment. To use your pesticide application equipment safely and effectively, study the manufacturer’s directions carefully. Some pesticide applications — such as airblast spraying, fumigation, aerial application, and chemigation — are highly specialized. You will need special training to use the equipment these applications require.

Sprayers

Sprayers are the most common pesticide application equipment. They are standard equipment for nearly every pesticide applicator and are used in every type of pest control operation. Sprayers range in size and complexity from simple, hand-held models to intricate machines weighing several tons.
Hand Sprayers

Hand sprayers are often used to apply small quantities of pesticides. They can be used in structures, and they can be used outside for spot treatments or in hard-to-reach areas. Most operate on compressed air supplied by a hand pump.

Advantages:
- simple to operate,
- easy to clean and store.

Limitations:
- pressure and output rate fluctuate,
- often provide too little agitation to keep wettable powders in suspension; must be shaken frequently.

Pressurized can (aerosol sprayer)

This type of sprayer consists of a sealed container of compressed gas and pesticides. The pesticide is driven through an aerosol-producing nozzle when the valve is activated. Pressurized cans usually have a capacity of less than 1 quart and are not reusable. Larger reusable cylinders are available for some specialty agricultural uses.

Trigger pump sprayer

With trigger pump sprayers, the pesticide is not packaged under pressure. Instead, the pesticide and diluent are forced through the nozzle by pressure created when the trigger is squeezed. The capacity of trigger pump sprayers ranges from 1 pint to 1 gallon.

Hose-end sprayer

This device causes a fixed rate of pesticide to mix with the water flowing through the hose to which it is attached. The mixture is expelled through a high-volume nozzle. These sprayers usually hold no more than 1 quart of concentrated pesticide, but because the concentrate mixes with the water, they may deliver 20 gallons or more of finished spray solution per fill.

Push-pull hand pump sprayer

This type of sprayer depends on a hand-operated plunger that forces air out of a cylinder, creating a vacuum at the top of a siphon tube. The suction draws pesticide from a small tank and forces it out with the air flow. Capacity is usually 1 quart or less.

Compressed air sprayer

This is usually a hand-carried sprayer that operates under pressure created by a self-contained manual pump. The air in the tank is compressed by the pump. The compressed air forces liquid pesticide through the hose and nozzle whenever the control valve is opened. A few types of these sprayers use carbon dioxide cartridges instead of a hand pump for compression. Capacity is usually $\frac{1}{2}$ to 3 gallons.

Bucket or trombone sprayer

These sprayers involve a double-action hydraulic pump, which is operated with a push-pull motion. The pesticide is sucked into the cylinder and pushed out through the hose and nozzle with the return stroke. Pressures up to 150 psi can be generated. The separate tank often consists of a bucket with a capacity of 5 gallons or less.

Backpack (knapsack) sprayer

One type of backpack sprayer is a compressed air sprayer with a harness that allows it to be carried on the operator’s back.

Another type of backpack sprayer has a hand-operated hydraulic pump that forces liquid pesticide through a hose and one or more nozzles. The pump is usually activated by moving a lever. A mechanical agitator plate may be attached to the pump plunger. Some of these sprayers can generate pressures of 100 pounds per square inch (psi) or more.

Capacity of both these types of backpack sprayers is usually 5 gallons or less.
Wheelbarrow sprayers are similar to backpack sprayers, but have a larger tank and longer hose line. The tank is mounted on a wheeled cart for easy transport. The capacity of these sprayers is usually less than 25 gallons.

Small Motorized Sprayers

Some small sprayers have all the components of larger field sprayers but usually are not self-propelled. They may be mounted on wheels so they can be pulled manually; mounted on a small trailer for pulling behind a small tractor; or skid-mounted for carrying on a small truck. They may be low-pressure or high-pressure, according to the pump and other components with which they are equipped.

Standard equipment includes a hose and an adjustable nozzle on a handgun. Some models have multi-nozzle booms. These sprayers are suitable for relatively small outdoor areas.

Advantages:
- Larger capacity than hand sprayers,
- Low- and high-pressure capability,
- Built-in hydraulic agitation,
- Small enough for limited spaces.

Limitations:
- Not suitable for general field use.

Estate sprayers

These sprayers are mounted on a two-wheel cart with handles for pushing. Trailer hitches are available for towing the units. Spray material is hydraulically agitated. Some models have 15- to 30-gallon tanks. Pumps deliver 1 1/2 to 3 gallons per minute at pressures up to 250 psi.

Larger models have 50-gallon tanks and pumps that deliver 3 to 4 gallons per minute at pressures up to 400 psi. Power is supplied by an air-cooled engine of up to 5 horsepower.

Power backpack sprayer

This backpack-type sprayer has a small gasoline-powered engine. The engine drives the pump, which forces the liquid pesticide from the tank through a hose and one or more nozzles. The engine also drives air blowers, which help propel the spray droplets. This model can generate high pressure and is best suited for low-volume applications of dilute or concentrated pesticide.

Power wheelbarrow sprayer

This sprayer, like the manually operated wheelbarrow sprayer, has a tank mounted on a wheel for easy transport. It may deliver up to 3 gallons per minute and can develop pressures up to 250 psi.

The 1 1/2- to 3- horsepower engine is usually air-cooled. The tank size ranges from 12 to 18 gallons. The spray mixture may be either mechanically or hydraulically agitated.

Large Power-Driven Sprayers (Low Pressure)

These sprayers are designed to distribute dilute liquid pesticides over large areas. They deliver a low to moderate volume of spray—usually 10 to 60 gallons per acre—at working pressures ranging from 10 to 80 psi.

These sprayers usually are mounted on tractors, trucks, or boats, but some are self-propelled. Roller pumps and centrifugal pumps are most often used and provide outputs from 5 to more than 20 gallons per acre. Tank sizes range from less than 50 gallons to 1,000 gallons. The spray material usually is hydraulically agitated, but mechanical agitation may be used.

Advantages:
- Medium to large tanks permit relatively large area to be covered per fill,
- Versatility.

Limitations:
- Low pressure limits pesticide penetration and reach.
Boom sprayers

Low-pressure sprayers often are equipped with sprayer booms ranging from 10 to 60 feet in length. The most common booms are between 20 and 35 feet long and contain several nozzles. The height of the sprayer boom must be easily adjustable to meet the needs of the job. Boom supports should allow the boom to be set at any height from 12 to 72 inches above the surface being sprayed. Many nozzle arrangements are possible, and special-purpose booms are available.

Boomless sprayers

Low-pressure sprayers that are not equipped with booms generally have a central nozzle cluster that produces a horizontal spray pattern. The resulting swath is similar to the pattern made by a boom sprayer. These sprayers are useful in irregularly shaped areas, because they can move through narrow places and avoid trees and other obstacles. Some low-pressure sprayers are equipped with a hose and handgun nozzle for applications in small or hard-to-reach areas.

Large Power-Driven Sprayers (High Pressure)

These sprayers are used to spray through dense foliage, thick animal hair, to the tops of tall trees, and into other areas where high-pressure sprays are necessary for adequate penetration and reach. Often called “hydraulic” sprayers, they are equipped to deliver large volumes of spray — usually 20 to 500 gallons per acre — under pressures ranging from 150 to 400 psi or more.

These sprayers usually are mounted on tractors, trailers, trucks, or boats, or are self-propelled. Piston pumps are used and provide outputs up to 60 gallons or more per minute. Large tanks (500 to 1,000 gallons) are required, because the application rate is usually 100 gallons per acre or more.

Mechanical agitators are usually standard equipment, but hydraulic agitators may be used. When fitted with correct pressure unloaders, these sprayers can be used at low pressures. All hoses, valves, nozzles, and other components must be designed for high-pressure applications.

High-pressure sprayers may be equipped with a hose and single handgun nozzle for use in spraying trees and animals. These sprayers also may be fitted with a boom for broadcast agricultural applications.

Advantages:
- provide good penetration and coverage of plant surfaces,
- usually well-built and long-lasting if properly cared for.

Limitations:
- large amounts of water, power, and fuel needed,
- high pressure may produce fine droplets that drift easily.

Airblast Sprayers

Airblast sprayers use a combination of air and liquid to deliver the pesticide to the surface being treated.

These sprayers usually include the same components as low-pressure or high-pressure sprayers, plus a high-speed fan. Nozzles operating under low pressure deliver spray droplets directly into the high-speed airstream. The air blast shatters the drops of pesticide into fine droplets and transports them to the target. The air blast is directed to one or both sides as the sprayer moves for-
ward, or it may be delivered through a movable nozzle.

Most airblast sprayers are trailer-mounted, but tractor-mounted models are available. Tank capacity ranges from 100 to 1,000 gallons. Most of these sprayers can be adapted to apply either high or low volumes of spray material as well as concentrates. Mechanical agitation of the spray mixture is usual. An airblast sprayer may cover a swath up to 90 feet wide and reach trees up to 70 feet tall.

**Advantages:**
- Good coverage and penetration,
- Mechanical agitation,
- High capacity,
- Can spray high or low volumes,
- Low pump pressures.

**Limitations:**
- Drift hazards,
- Use of concentrated pesticides may increase chance of dosage errors,
- Not suitable for windy conditions,
- Hard to confine discharge to limited target area,
- Difficult to use in small areas,
- High power requirement and fuel use.

**Other Sprayers**

**Ultra-low-volume (ULV) sprayers**

These are sprayers that use special pesticide concentrates. ULV sprayers may be hand-held or mounted on either ground equipment or aircraft.

**Advantage:**
- No water is needed, so less time and labor are involved.

**Limitations:**
- Drift hazards,
- Coverage may not be thorough,
- High concentrates present safety hazards.

- Use of concentrated pesticides may increase chance of dosage errors,
- Few pesticides are labeled for ULV.

**Controlled droplet applicators (CDA)**

These applicators use a spinning disk (or cup) that breaks the liquid into uniformly sized droplets by centrifugal force. The droplets may be carried to the target by gravity or by an airstream created by a fan. Power to spin the disk or cup is provided by a small electric or hydraulic motor. Most CDA’s do not use a pump. CDA’s range in size from a small hand-held type to large tractor-mounted and trailer-mounted units.

**Advantages:**
- Requires a low volume of water,
- Produces narrower range of droplet sizes than conventional nozzles, thus reducing drift,
- Droplet size can be adjusted by speed of rotation.

**Limitations:**
- Gravity type may not penetrate foliage well,
- Not suitable for use in windy conditions.

**Electrostatic sprayers**

Electrostatic sprayer systems give the pesticide a positive electric charge as it leaves the nozzles. Plants naturally have a negative charge, so the positively charged pesticide is attracted to the plants. The spray is directed horizontally through or above the crop (depending on the pesticide being applied).

**Advantages:**
- Pesticide adheres to foliage well, so less pesticide is needed per acre,
- Coverage is more even than with other types of equipment,
- Minimizes the likelihood of drift.

**Limitation:**
- Useful only for application to foliage.

**Sprayer Parts**

**Large Tanks**

Tanks should have large openings for easy filling and cleaning. Tanks should be designed to allow the use of strainers during filling, and also should allow mechanical or hydraulic agitation devices to be installed. The tank should be made of corrosion-resistant material such as stainless steel or fiberglass. If made of mild steel, it should have a protective lining or coating.

The tank should have a large drain, and other outlets should be sized to the pump capacity. If you use dual tanks, make sure the plumbing allows both tanks to have agitation and adequate withdrawal rates. All tanks should have a gauge to show the liquid level. External gauges should be protected to prevent breakage. All tanks should have a shutoff valve for storing liquid pesticide temporarily while other sprayer parts are being serviced.

**Pumps**

The pump must have enough capacity to supply the needed volume to the nozzles and to the hydraulic agitator (if necessary) and to maintain the desired pressure. The pump parts should resist corrosion, and they should be abrasion-resistant if abrasive materials such as wettable powders will be used. Select gaskets, plunger caps, and impellers that resist the swelling and chemical
breakdown caused by many liquid pesticides. Consult your dealer for available options.

Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. Pumps will be damaged if operated when dry or with restricted flow at the inlet or outlet. Pumps depend on the spray liquid for lubrication and for cooling the heat caused by friction.

**Roller pumps**

Roller pumps are the most widely used of all sprayer pumps. They provide moderate volumes (8 to 30 gpm) at low to moderate pressure (10 to 300 psi). Often used on low-pressure sprayers, roller pumps are self-priming. The pump case is usually cast iron or a nickel-iron alloy.

The rollers, made of nylon, Teflon, or rubber, wear rapidly in wettable powders but are replaceable. A pump subjected to such wear should have a capacity about 50 percent greater than that needed to supply the nozzles and agitator. This reserve capacity will extend the life of the pump.

Roller pumps are usually the best choice for emulsifiable concentrates, soluble powders, and other pesticide formulations that are not abrasive.

**Gear pumps**

Gear pumps are used on sprayers with low operating pressures. They provide low to moderate volume (5 to 65 gpm) at low to moderate pressures (20 to 100 psi). Gear pumps are self-priming, but the self-priming ability is rapidly lost as the pump wears.

Gear pumps are designed for use with formulations that use oil as a diluent. They wear rapidly when wettable powders are used. The parts are generally not replaceable. The pump is not affected by most solvents, because all parts are metal. The pump case may be bronze with stainless steel impellers, or it may be made entirely of bronze.

**Centrifugal pumps**

Centrifugal pumps are adaptable to a wide variety of spray applications. Generally, they deliver high volume (up to 200 gpm) at low pressures (5 to 70 psi); however, two-stage pumps develop high pressures (up to 200 psi). Pressure regulators and relief valves are not necessary.

Centrifugal pumps are not self-priming and must be mounted below the tank outlet or provided with a built-in priming system. Centrifugal pumps are well adapted for spraying abrasive materials, because the impeller does not contact the pump housing. Many models are easily repairable. The pump case is usually iron; the impeller is iron or bronze.

**Diaphragm pumps**

Diaphragm pumps are generally used to deliver low volume (3 to 10 gpm) at low to moderate pressures (10 to 100 psi), but they also can be used for high-volume, high-pressure applications.

Diaphragm pumps withstand abrasion from wettable powder mixtures much better than gear, roller, or piston pumps because the spray mixture does not contact any moving metal parts except the valves. Diaphragm pumps are self-priming. The rubber or neoprene diaphragm may be damaged by some solvents; the pump case is usually iron.

**Piston pumps**

Piston pumps deliver low to medium volumes (2 to 60 gpm) at low to high pressures (20 to 800 psi). Used for high-pressure sprayers or when both low and high pressures are needed, piston pumps are self-priming. They have replaceable piston cups made of leather, neoprene, or nylon fabric, making the pump abrasion-resistant and capable of handling wettable powders for many years. The cylinders are iron, stainless steel, or porcelain-lined. The pump casing is usually iron.

**Strainers (Filters)**

Pesticide mixtures should be filtered to remove dirt, rust flakes, and other foreign materials from the tank mixture. Proper filtering protects the working parts of the sprayer from undue wear and avoids time loss and uneven application caused by clogged nozzle tips.

Filtering should be progressive, with the largest mesh screens in the filler opening and in the suction line between the tank and the pump. Filters should be keyed
to the size of the nozzle opening. Total screen area should be large enough so that the flow will not be restricted. This requires at least 2 square inches of screen area for each gpm of flow in the suction line.

Put a smaller mesh strainer in the pressure line between the pump and the pressure regulator, with at least 1 square inch of screen area for each gpm of flow. Put the finest mesh strainer on the nozzle body. Do not use a strainer in the suction line of a centrifugal pump, but be sure the tank has a strainer to take out large particles.

In general, strainers should be placed:
- on the filler opening (12 to 25 mesh),
- on the suction or supply line to the pump (15 to 40 mesh),
- between the pressure relief valve and the boom (25 to 100 mesh),
- on the nozzle body (50 to 100 mesh).

Clean strainers after each use, or during use if they become clogged. A shutoff valve is needed between the tank and the suction strainer to allow the strainer to be cleaned without draining the tank. Replace damaged or deteriorated strainers.

Strainers are your best defense against nozzle plugging and pump wear. Nozzle screens should be as large as nozzle size permits; however, the screen opening should be less than the nozzle opening. Check nozzle catalogs for the proper screen size for each nozzle.

**Hoses**

Select neoprene, rubber, or plastic hoses that:
- have burst strength greater than the peak operating pressures,
- have a working pressure at least equal to the maximum operating pressure,
- resist oil and solvents present in pesticides,
- are weather resistant.

Suction hoses should be reinforced to resist collapse. They should be larger than pressure hoses, with an inside diameter equal to or larger than the inlet part of the pump. All fittings on suction lines should be as large as or larger than the inlet part of the pump.

Keep hoses from kinking or being rubbed. Flush hoses after use and wash them often to prolong life. During the off-season, store the sprayer out of the sun. Replace hoses at the first sign of surface deterioration (cracking or checking).

**Pressure Gauges**

Pressure gauges monitor the line pressure of your spraying system. They must be accurate and have the range needed for your work. For example, a 0 to 100 psi gauge with 2-pound gradations would be adequate for most low-pressure sprayers.

Check frequently for accuracy against an accurate gauge. Excess pressure will destroy a gauge. If yours does not zero, replace it. Use gauge protectors to guard against corrosive pesticides and pressure surges.

**Pressure Regulators**

The pressure regulator controls the pressure and, indirectly, the quantity of spray material delivered by the nozzles. It protects pump seals, hoses, and other sprayer parts from damage caused by excessive pressure.

Keep the bypass line from the pressure regulator to the tank fully open and unrestricted. The bypass line should be large enough to carry the total pump output without excess pressure buildup. The pressure range and flow capacity of the regulator must match the pressure range you plan to use and the capacity of the pump. Never attach hydraulic agitation devices to the bypass line discharge.

Pressure regulators are usually one of three types:

- **Throttling valves** simply restrict pump output, depending on how much the valve is open. These valves are used with centrifugal pumps, whose output is very sensitive to the amount of restriction in the output line.

- **Spring-loaded bypass valves** (with or without a diaphragm) open or close in response to changes in pressure, diverting more or less liquid back to the tank to keep pressure constant. These valves are used with roller, diaphragm, gear, and small piston pumps.

- **Unloader valves** work like a spring-loaded bypass valve when the sprayer is operating. However, when the nozzles are shut down, they reduce strain on the pump by moving the overflow back into the tank at low pressure. These valves
should be used on larger piston and diaphragm pumps to avoid damage to the pump or other system components when the nozzles are cut off.

**Agitators**

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

**Bypass agitators**

Bypass agitation uses the returning liquid from the pressure relief valve to agitate the tank. The return must extend to the bottom of the tank to prevent excessive foaming. Bypass agitation is sufficient for soluble powders and for liquid formulations such as solutions and emulsifiable concentrates that do not require much agitation.

Do not use bypass agitation for wettable powders or in tanks larger than 55 gallons, unless the system has a centrifugal pump. Centrifugal pumps usually have large enough outputs to make bypass agitation adequate even for wettable powders in tanks less than 100 gallons.

**Hydraulic (jet action) agitators**

Hydraulic agitation is provided by the high-pressure flow of surplus spray material from the pump. Hydraulic agitation is required for wettable powder and flowable formulations in small tanks and for liquid formulations in 100-gallon or larger tanks with gear, roller, piston, or diaphragm pumps.

The jet or jets for a hydraulic agitator are located at the bottom of the tank. The agitator is connected to the pressure side of the pump. Never place jet agitator nozzles in the bypass line.

The pump and tank capacity and operating pressure determine the minimum number of jets:
- 55 gallons = 1 or more jets,
- 100 to 150 gallons = 3 or more jets,
- 200 gallons and larger = 5 or more jets.

**Mechanical agitation**

Wettable powder formulations are best mixed and kept in suspension with mechanical agitation. The mechanical agitator usually consists of flat blades or propellers mounted on a shaft that is placed lengthwise along the bottom of the tank. The paddles or propellers are rotated by the engine to keep the material well mixed. Mechanical agitators are usually found only on large high-pressure hydraulic sprayers.

**Control Valves**

Quick-acting cutoff valves should be located between the pressure regulator and the nozzles to provide positive on-off action. These control valves should be rated for the pressures you intend to use and should be large enough not to restrict flow when open. Cutoff valves to stop all flow or flow to any section of the spraying system should be within easy reach of the sprayer operator.

There are many kinds of control valves. Mechanical valves must be accessible to the operator’s hand; electrically operated valves permit remote control of flow. For tractors or self-propelled sprayers with enclosed cabs, remote-controlled valves permit all hoses carrying pesticides to be kept safely outside the cab.

**Nozzles**

Most nozzles have four major parts: the nozzle body, the cap, the strainer (screen), and the tip or orifice plate. They also may include a separate spinner plate. Successful spraying depends on
the correct selection, assembly, and maintenance of the nozzles.

The nozzle body holds the strainer and tip in proper position. Several types of tips that produce a variety of spray patterns may be interchanged on a single nozzle body made by the same manufacturer.

The cap is used to secure the strainer and the tip to the body. The cap should not be overtightened.

The nozzle strainer is placed in the nozzle body to screen out debris that may clog the nozzle opening. The type of nozzle strainer needed depends on the size of the nozzle opening and the chemical being sprayed.

Special nozzle screens equipped with a check valve help prevent nozzle dripping. Check valves should be used in situations where a sprayer must be stopped and started frequently, such as in small target areas, near sensitive crops or areas, indoors, or for right-of-way treatments. The operator must check these spring-loaded ball valves frequently to be sure they are working properly.

Nozzle tips break the liquid pesticide into droplets. They also distribute the spray in a predetermined pattern and are the principal element that controls the rate of application. Nozzle performance depends on:
- nozzle design or type,
- operating pressure,
- size of the opening,
- discharge angle,
- distance of nozzle from the target.

Nozzle Patterns

Nozzle patterns are of three basic types: solid stream, fan, and cone. Some special-purpose nozzle tips or devices produce special patterns. These include "raindrops," "flooding," and others that produce wide-angle fan or cone-shaped patterns.

Solid stream nozzles

These nozzles are used in handgun sprayers to spray a distant or specific target such as livestock or tree pests. They also used mostly for uniform spray coverage of surfaces; for example, broadcast soil applications of herbicides or insecticides.

The regular flat fan nozzle tip makes a narrow oval pattern with tapered ends. It is used for broadcast herbicide and insecticide spraying at 15 to 60 psi. The pattern is designed to be used on a boom and to be overlapped 30 to 50 percent for even distribution. Spacing on the boom, spray angle, and boom height determine proper overlap and should be carefully controlled.

The even flat fan nozzle makes a narrow oval pattern. Spray delivery is uniform across its width. It is used for band spraying and for treating walls and other surfaces. It is not useful for broadcast applications. Boom height and nozzle spray angle determine the width of the band sprayed.

The flooding (flat fan) nozzle delivers a wide-angle flat spray pattern. It operates at very low pressure and produces large spray droplets. Its pattern is fairly uniform across its width but not as even as the regular flat fan nozzle pattern. If used for broadcast spraying, it should be overlapped to provide double coverage. It is often used for applying liquid fertilizers or fertilizer-pesticide mixtures or for directing herbicide sprays up under plant canopies.

Cluster nozzles are used either without a boom or at the end of booms to extend the effective swath width. One type is simply a large flooding deflector nozzle that will spread spray droplets over a swath up to 70 feet wide from a single nozzle tip. Cluster nozzles are a combination of a center-discharge and two or more off-center-discharge fan nozzles.
The spray droplets vary in size from very small to very large. The small droplets may cause a drift problem. Coverage may be variable because the spray pattern is not uniform. Since no boom is required, these nozzles are particularly well suited for spraying hedgerows, fence rows, and other hard-to-reach locations where uniform coverage is not critical.

**Cone pattern nozzles**

Hollow and solid cone patterns are produced by several types of nozzles. These patterns are used where penetration and coverage of plant foliage or other irregular targets are desired. They are most often used to apply fungicides and insecticides to foliage, although some types are used for broadcast soil applications of herbicides or fertilizers or combinations of the two.

When cone pattern nozzles are used for airblast sprayer broadcast application, they should be angled to spray between 15° and 30° from the horizontal and should be spaced at the top of the manifold so the spray pattern will overlap up to 100 percent.

The side-entry hollow cone or “whirl-chamber” nozzle produces a very wide angle hollow cone spray pattern at very low pressures. It has a large opening and resists clogging. Because of the wide spray angle, the boom can be operated low, reducing drift. Spacing for double coverage and angling 15° to 45° to the rear is recommended for uniform application. These nozzles may be used in place of flat fan nozzle tips in broadcast applications.

Core-insert cone nozzles produce either a solid or hollow cone spray pattern. They operate at moderate pressures and give a finely atomized spray. They should not be used for wettable powders because their small passages clog easily and they wear rapidly due to abrasion.

Disk-core nozzles produce a cone-shaped spray pattern, which may be hollow or solid. The spray angle depends on the combination of disk and core used and also, to some extent, on the pressure. Disks made of very hard materials resist abrasion well, so these nozzles are recommended for spraying wettable powders at high pressures.

Adjustable cone nozzles change their spray angle from a wide cone pattern to a solid stream when the nozzle collar is turned. Many manual sprayers are equipped with this type of nozzle. Handguns for power sprayers have adjustable nozzles that usually use an internal core to vary the spray angle.

**Nozzle Materials**

Most nozzle parts are available in several materials. Here are the main features of each kind:

**Brass:**

- Resists corrosion from most pesticides.
- Wears quickly from abrasion.
- Probably the best material for general use.
- May be corroded by liquid fertilizers.

**Plastic:**

- Will not corrode,
- Resists abrasion better than brass,
- May swell when exposed to some solvents,
- Useful life about equal to that of brass nozzles.

**Stainless steel:**

- Resists abrasion, especially if hardened,
- Good corrosion resistance,
- Suits high pressures, especially with wettable powders,
- Lasts longer than brass.

**Aluminum:**

- Resists some corrosive materials,
- Easily corroded by some fertilizers,
- Useful life much shorter than brass.

**Tungsten carbide and ceramic:**

- Highly resistant to abrasion and corrosion,
- Best material for high pressures and wettable powders,
- Lasts much longer than brass.

**Sprayer Selection, Use, and Care**

Choosing the correct sprayer for each job is important. Your sprayer should be:

- Designed to do the job you want to do,
- Durable,
- Convenient to fill, operate, and clean.

Always read and follow the operator's manuals. They will tell you how to use and care for your spray equipment. After each use, rinse the entire system. Check for leaks in lines, valves, seals, and tank. Remove and clean nozzles, nozzle screens, and strainers.

Be alert for nozzle clogging and changes in nozzle patterns. If nozzles clog or other trouble
occurs in the field, be careful not to contaminate yourself while correcting the problem. Shut off the sprayer and move it to the edge of the field before dismounting. Wear personal protective equipment while making repairs. Clean clogged nozzles only with a non-metal nozzle-cleaning tool. Sharp metal can ruin the nozzle. Never use your mouth to blow out a nozzle.

To prepare spray equipment for storage, follow manufacturer’s instructions. If there are no instructions, rinse and clean the system. Then fill the tank almost full with clean water. Add a small amount of new lightweight oil to the tank. Coat the system by pumping this mixture out through the nozzles or handgun. Drain the pump and plug its openings or fill the pump with lightweight oil or antifreeze. Remove nozzles and nozzle screens and store in lightweight oil or diesel fuel.

**Aerosol Generators and Foggers**

Aerosol generators and foggers convert special formulations into very small, fine droplets (aerosols). Single droplets cannot be seen, but large numbers of droplets are visible as a fog or mist. Aerosol generators and foggers usually are used to completely fill a space with a pesticidal fog. Some insects in the treated area are killed when they come in contact with the poison. Other insects are simply repelled by the mist and return quickly after it has settled.

**Thermal foggers**, also called thermal generators, use heat to vaporize a special oil formulation of a pesticide. As the pesticide vapor is released into the cooler air, it condenses into very fine droplets, producing a fog.

Other aerosol generators (cold foggers) break the pesticide into aerosols by using mechanical methods such as:
- rapidly spinning disks,
- extremely fine nozzles and high pressure (atomizing nozzles),
- strong blasts of air.

**Advantages:**
- penetration in dense foliage,
- penetration of cracks and crevices,
- some indoor devices are automatic and do not require presence of applicator.

**Limitations:**
- aerosols and fogs drift easily from target area,
- no residual control — pests may return to the area as soon as fog dissipates,
- risk of explosion in enclosed areas.

**Selection, Use, and Care**

Choose an aerosol generator according to where you will use it — indoors or outdoors. Aerosol and fog generators are manufactured for many special uses. There are truck- and trailer-mounted machines for use outdoors. Most hand-operated or permanently mounted automatic machines are for use indoors.

In general, use and care for an aerosol generator as you would a sprayer. They do require several special precautions, however:
- Be sure that the pesticides used in the aerosol and fog generators are registered for that use.
- Keep the pesticides on the target.
- Because aerosol and fog formulations are easily affected by weather conditions during application, follow special use instructions.

- The operator, other people, and animals should stay out of the fog or smoke cloud.

**Soil Fumigation Equipment**

The equipment needed for applying soil fumigants depends on the kind of fumigant being used. There are two types of fumigants:
- low-pressure (low volatility) liquid fumigants, and
- highly volatile fumigants that remain as liquids only when placed under pressure.

**Low-Pressure Liquid Fumigators**

Equipment for applying low-pressure fumigants varies widely, but uses two basic designs for metering and delivering the fumigant. These delivery systems are either pressure (pump)-fed or gravity-fed.

**Pressure-fed** applicators have a pump and metering device and deliver fumigant under pressure to the nozzle openings (orifices) as with a low-pressure sprayer.

Gravity-flow applicators use the size of the nozzle orifice and the pressure created by gravity to regulate the output of fumigant. Constant speed is necessary to maintain a uniform delivery rate. Most applicators have a device that keeps the pressure at the orifice constant as the tank or container of fumigant empties. Needle valves, orifice plates or disks, and capillary tubes are used to adjust the flow rate.

Low-pressure fumigators usually use the soil itself or water to keep the fumigant from vaporizing and moving off target too
quickly. Some of the methods used are:
- soil injection,
- soil incorporation,
- drenching or flooding.

**Soil injection**

Soil injectors use a variety of mechanisms to insert the fumigant into the soil (usually at least 6 inches deep) and then cover the area with soil to seal in the fumigant. The principal mechanisms include chisel cultivators, blades, or shovels; sweep cultivator shovels; planter shoes; and plows.

**Soil incorporation**

Soil incorporators are used when applying low-volatility fumigants. The fumigant usually is sprayed onto the soil surface. The area is immediately cultivated, usually to a depth of 5 inches or less, to incorporate the fumigant. Then the soil is compacted with a drag, float, or cultipacker. Power-driven rotary cultivators are also used.

**Drenching or flooding**

These methods use water as a sealant. The fumigant may be applied in the water as a drench. The equipment needed depends on the size and timing of the application. The fumigant-containing water may be applied with a sprinkling can, sprinkler system, or irrigation equipment.

Another way to apply the fumigant is to first spray the pesticide on the soil surface and then immediately flood the area. The depth of the water seal (usually 1/2 to 4 inches of wetted soil) depends on the volatility of the fumigant.

**High-Pressure Fumigators**

Effective application of highly volatile fumigants depends on tightly sealing the soil with tarps, plastic film, or similar covers. There are two major methods of using vapor-proof tarps:
- Tarp supported off the ground and sealed around the edges; fumigant introduced under the tarp.
- Tarp applied to the soil by the injection chisel equipment immediately after the fumigant is injected.

Highly volatile fumigants must be handled in pressurized containers or tanks. The equipment is similar to gravity-flow low-pressure fumigators. The pressure in the tank maintains the line pressure to the nozzle orifices.

The tank is either pre-charged with enough pressure to empty its contents, or an inert pressurized gas is fed into the tank during application to displace the fumigant. A gas regulator maintains uniform pressure in the system. To ensure accurate application, the fumigant must be under enough pressure to maintain a liquid state in the tank, pressure lines, manifold, and metering devices.

**Selection of Soil Fumigation Equipment**

Pumps, tanks, fittings, nozzles or metering orifices, and lines must be corrosion resistant. Soil injection knives should be designed to shed crop residues and allow the soil to seal over the fumigant. Choose high-pressure fumigators designed to handle both the pressure created by the fumigant and the corrosive action of the product you plan to use.

**Dusters and Granule Applicators**

**Dusters**

Dusters are used only occasionally in outdoor agricultural situations, because of the high probability of drift. Dust applications are more common in greenhouses and other enclosed agricultural areas.

**Hand dusters**

Hand dusters may consist of a squeeze bulb, bellows, tube, shaker, sliding tube, or a fan powered by a hand crank.

**Advantages:**
- lightweight—do not require water,
- the pesticide is ready to apply without mixing,
- good penetration in confined spaces.

**Limitations:**
- dust may not stick to foliage,
- dust is difficult to direct,
- drift potential is high.

**Power dusters**

Power dusters use a powered fan or blower to propel the dust to the target. They include knapsack or backpack types, units mounted on or pulled by tractors, and specialized equipment for treating seeds. Their capacity in area treated per hour compares favorably with some sprayers.

**Advantages:**
- lightweight — no water required,
- simply built,
- easy to maintain.

**Limitations:**
- drift hazards,
- application may be less uniform than with sprays,
- dust may not stick to foliage.
Granule Applicators

Granule applicators distribute granular pesticides by several different methods, including:
- forced air,
- spinning or whirling disks (fertilizer spreaders),
- multiple gravity-feed outlets (lawn spreaders, grain drills),
- soil injectors (furrow treatments),
- ram-air (agricultural aircraft).

Granule applicators may be designed to apply the pesticides:
- broadcast—even distribution over the entire area,
- to specific areas—banding, infurrow, side-dress,
- by drilling—soil incorporation or soil injection.

Advantages:
- simple in design,
- eliminates mixing—no water needed,
- minimal drift hazard,
- low exposure hazard to applicator.

Limitations:
- limited use against some pests because granules will not adhere to most foliage,
- need to calibrate for each different granular formulation,
- spinning disk types may give poor lateral distribution, especially on side slopes.

Selection, Use, and Care

Look for a power duster that is easy to clean. It should give a uniform application rate as the hopper is emptied. Look for both hand and power dusters that direct the dust cloud away from the user.

Choose a granule applicator that is easy to clean and fill. It should have mechanical agitation over the outlet holes. This prevents clogging and helps keep the flow rate constant. Application should stop when drive stops even if outlets are still open.

Both dusters and granule applicators are speed-sensitive, so maintain uniform speed. Do not travel too fast for ground conditions. Bouncing equipment will cause the application rate to vary. Stay out of any dust created by action of the equipment.

Watch band applicators to see that band width stays the same. Small height changes due to changing soil conditions may cause rapid changes in band width. Clean equipment as directed by the operator’s manual.

Animal Application Equipment

Dipping Vats

Dipping vats are large tanks (vats) of liquid pesticide mixture used to treat livestock for external parasites. Portable dipping vats are usually trailer-mounted tanks with a set of folding ramps and railings. The animals are driven up the ramp onto a platform and forced into the tank so they are completely immersed. The animal’s head may have to be pushed under the surface.

Maintaining the proper concentration of pesticide in the vat is very important. The vat should be kept at least 7/8 full at all times. Replenishment is usually based on a knowledge of the amount of liquid removed from the vat.
Spray-Dip Machines

Spray-dip machines are used to treat livestock for external parasites. A spray-dip machine usually consists of a trailer-mounted chute with solid walls and gates at either end. The chute is located above a shallow tank and is equipped with several rows of large nozzles mounted in a manner that directs the spray mixture to thoroughly cover each animal. A large centrifugal pump supplies the pesticide to the nozzle. Surplus and runoff spray falls back into the tank where it is filtered and recycled to the nozzles.

Face and Back Rubbers and Dust Bags

Face and back rubbers and dust bags are containers of dry or liquid pesticide formulation used to control external parasites of livestock. The devices are hung or mounted in areas adjacent to high livestock traffic, such as feeding troughs, waterers, and narrow gate entrances. When the animal rubs against the device, the pesticide is transferred to the animal's face, back, sides, or legs.

Dust Boxes

Dust boxes are used mainly in raised wire battery-type cages for laying hens or other poultry. These boxes contain a pesticide dust used to control poultry pests, usually mites. Birds wallow in the boxes and pick up the dust on their feathers and skin.

Bait Application Equipment

Bait Stations

Bait stations hold pesticide-treated food that attracts target pests. They are used for insect control around poultry and livestock housing and for vertebrate control around crops, commodities, and agricultural buildings.

Bait Applicators

Bait applicators are used to apply pesticides to control gophers, moles, and other underground vertebrate pests. Some hand-operated models inject the poisoned bait directly into underground burrows. Mechanical models are tractor-mounted machines that form artificial burrows that intersect with natural burrows. When the pests use the artificial burrows, they feed on the bait.

Specialized Application Equipment

You may sometimes use other types of equipment that is designed for specialized applications. Some of this specialized equipment is intended for application of herbicides. Other specialized application equipment is for applying pesticides through irrigation or watering systems.

Specialized Application Equipment for Herbicides

Some application equipment is designed to apply herbicides so that the herbicide contacts the weeds, but does not contact desirable plants in the treated area. This equipment includes:

- recirculating sprayers,
- shielded applicators,
- wiper applicators,
- wax bar applicators.

Recirculating sprayers

These devices usually are used to apply contact herbicides to weeds that are taller than the crop in which they are growing. Solid streams of highly concentrated
herbicides are directed across rows above the crop. The system prevents the herbicide from contacting the desirable plants. Spray material that is not intercepted by the weeds is caught in a box or sump on the opposite side of the row and is recirculated.

Advantages:
- uses small quantities of pesticide,
- less pesticide moves off target and into environment,
- permits treatment of weeds that have escaped other control measures,
- protects susceptible nontarget plants from injury.

Limitations:
- use limited to special situations.

Shielded applicators

These applicators direct the herbicide onto the weeds while shielding desirable plants from the herbicide.

Wiper applicators

Sometimes called “wick” or “rope” applicators, these devices are used to apply herbicides selectively to weeds in crop areas. Wicks made of rope, rollers made of carpet or other material, or absorbent pads made of sponges or fabric are kept wet with a concentrated mixture of herbicide and water and brought into direct contact with weeds. The herbicide is “wiped” onto the weeds, but does not come in contact with the crop.

Application may be to tall weeds growing above the crop or to lower weeds between rows, depending on the way the wiper elements are designed. Pumps, control devices, and nozzles are minimal or are eliminated altogether, and tanks are quite small because of the small amount of liquid applied.

Advantages:
- simple to operate,
- no drift,
- uses small amount of pesticide.

Limitations:
- useful only in special situations,
- difficult to calibrate.

Wax bars

Herbicides are sometimes applied with wax bars that are impregnated with herbicides. The bars are dragged slowly over the area to be protected.

Advantages:
- no drift,
- no calibration.

Limitations:
- highly specialized, not readily available.

Irrigation Application Equipment

Irrigation or watering systems can be equipped to deliver pesticides to a target. Known as “chemigation,” this is a common method for applying pesticides in many irrigated areas. Accurate calibration and distribution are achieved by metering a large volume of dilute pesticide into the irrigation system. Antisiphon check valves prevent contamination of the irrigation water source and switch valves prevent overflow into the slurry feed tank.

Advantages:
- convenient,
- field access unnecessary.

Limitations:
- constant agitation needed in slurry tank,
- application of more water per acre than recommended on label will cause some pesticides to leach,
- sprinkler distribution must have appropriate overlap pattern for uniform delivery,
- injection of pesticides into flood and furrow irrigation systems may result in uneven concentrations of pesticides throughout the field, depending on soil permeability and field contours.
Test Your Knowledge

Q. Match each sprayer type below with the pest control situation in which it would be most useful.

1. Spot treatment of a few weeds in a small area. A. Boomless sprayer
2. Broadcast application of herbicide to a 10-acre field. B. High-pressure (hydraulic) sprayer
3. Broadcast application in an area where the equipment must move through narrow places and around trees. C. Hand-operated sprayer
4. Application of herbicide to a stand of tall trees with dense foliage. D. Boom sprayer

A. 1–C, 2–D, 3–A, 4–B

Q. Match the following types of sprayers with the correct statements about their advantages and limitations:

1. Simple to operate; pressure and output not steady; little agitation. A. ULV sprayers
2. Larger capacity than hand sprayers; deliver both low and high pressures; not big enough for general field use. B. Hand-operated sprayers
3. Cover large area with each tankful; limited penetration and reach. C. Large high-pressure sprayers
4. Good penetration and coverage; need large amounts of water, power, and fuel; output drifts easily. D. Large low-pressure sprayers
5. Good coverage and penetration using low pump pressures; use of concentrates makes dosage errors more likely. E. Electrostatic sprayers
6. No water needed; use of high concentrates presents safety hazards; few pesticides labeled for this use. F. Airblast sprayers
7. Pesticide adheres to foliage well; little drift hazard; useful only for foliage applications. G. Small motorized sprayers

Q. Match the following types of sprayer pumps with the correct statements about their features:

1. Provide moderate volumes at low to moderate pressures; self-priming; best with non-abrasive formulations.
   A. Centrifugal pumps

2. Used with low-pressure sprayers to spray oil-based formulations; all parts are metal.
   B. Diaphragm pumps

3. High volume; not self-priming; good for abrasive formulations.
   C. Gear pumps

4. Generally used to deliver low volumes, but also useful for high-volume, high-pressure applications; self-priming; good with abrasive formulations but may be damaged by some solvents.
   D. Piston pumps

5. Used for high-pressure sprayers or when both low and high pressures are needed; self-priming; piston cups can be replaced when worn by abrasives.
   E. Roller pumps

A. 1–E, 2–C, 3–A, 4–B, 5–D,

Q. Why are strainers used in a sprayer system?

A. Strainers remove dirt and other foreign materials from the tank mixture, protect the working parts of the sprayer system from wear, and prevent nozzle clogging.

Q. Select the correct answers to complete the following statements about sprayer parts:

1. A good sprayer tank is easy to fill, easy to clean, and:
   A. is corrosion-resistant.
   B. has a large drain opening.
   C. is equipped with a shutoff valve.
   D. has a gauge to show the liquid level.
   E. all of the above

2. A pump should have enough capacity to supply the needed volume to the nozzles and to:
   A. empty the tank in 5 minutes or less.
   B. maintain the desired pressure at the nozzles.
   C. deliver volume or pressure at least 15 percent greater than the manufacturer’s recommendations.

3. The suction hoses on a sprayer system should be:
   A. larger than the pressure hoses.
   B. smaller than the pressure hoses.
   C. the same size as the pressure hoses.

4. Pressure gauges can be damaged by:
   A. excess pressure.
   B. pressure that is too low.
   C. corrosive pesticides.
   D. A and C

5. A quick-acting cutoff valve should be located:
   A. between the pump and the pressure regulator.
   B. between the pressure regulator and the nozzles.
   C. between the bypass line and the agitator.

A. 1–E, 2–B, 3–A, 4–D, 5–B
Q. Match the following types of pressure regulators with the correct description:

1. Valve is manually adjusted; restriction of pump output depends on how much the valve is open.  
   A. Spring-loaded bypass valve
2. Valve opens or closes in response to changes in pressure.  
   B. Unloader valve
3. Valve allows overflow to move back to tank when nozzles are shut down.  
   C. Throttling valve

A. 1–C, 2–A, 3–B

Q. What are the three main types of agitation that can be used in spray tanks? Which type is best for wettable powders and other formulations that need a lot of agitation?

A. The three main types of agitation are:
   - bypass agitation,
   - hydraulic (jet action) agitation, and
   - mechanical agitation (best method for keeping wettable powders in suspension).

Q. On the diagram below, label the four main parts of the nozzle.

A. __________  B. __________  C. __________  D. __________

A. A–body, B–cap, C–strainer (screen), D–tip

Q. Match the nozzle types below with the correct uses:

1. Solid stream nozzles  
   A. Used for uniform spray coverage of surfaces, such as in broadcast application of herbicides to soil.
2. Fan pattern nozzles  
   B. Used to get good penetration and coverage when applying fungicides or insecticides to foliage.
3. Cone pattern nozzles  
   C. Used in handgun sprayers for spot treatments and crack and crevice treatments; attached to boom to apply narrow band.

A. 1–C, 2–A, 3–B

Q. What is the best way to clean a clogged nozzle?

A. First, shut off the sprayer and move it out of the pesticide-treated area. Wear personal protective equipment to keep the pesticide from getting on your skin. Clean the clogged nozzle with a non-metal nozzle-cleaning tool.
Q. List at least one advantage and one limitation of aerosol generators and foggers.

A. Advantages:
   - good penetration of dense foliage,
   - good penetration of cracks and crevices,
   - some indoor devices are automatic and do not require the applicator to be present.

Limitations:
   - aerosols and fogs drift easily from target area,
   - no residual control — pests may return to the area as soon as fog dissipates,
   - risk of explosion in enclosed areas.

Q. Match the following types of soil fumigation equipment with the features that describe them:

1. Pressure-fed applicators  
A. Apply highly volatile fumigants that require target area to be sealed with a tarp or other cover.

2. Gravity-flow applicators  
B. Have a pump and metering device to deliver the fumigant to nozzle openings under pressure.

3. High-pressure fumigators  
C. Fumigant output regulated by size of nozzle openings and the pressure created by gravity.

A. 1-B, 2-C, 3-A

Q. Why are dusters not used often in outdoor agricultural pest control?

A. Dusters are often not a good choice for outdoor use because pesticide dusts drift away from the target easily.

Q. In which of the following situations would a granule applicator probably NOT be a good choice?
   A. Broadcast application of pesticide when drift may be a problem.
   B. Application of pesticide to plant foliage.
   C. Aerial application of pesticide.
   D. Soil incorporation of pesticide.

A. B

Q. Which of the following types of equipment are left in place so that livestock or poultry will be self-treated when their normal activities bring them into contact with the devices?
   A. Spray-dip machines
   B. Dust boxes
   C. Face and back rubbers
   D. Dust bags
   E. Dipping vats

A. B, C, and D
Q. Match the following specialized application equipment with the correct descriptions of their functions:

1. Recirculating sprayers  A. Apply pesticides through irrigation systems
2. Shielded applicators  B. Directs pesticide above crop to treat taller weeds; collects excess spray material for reuse.
3. Wiper applicators  C. Dragged slowly over area to be treated.
4. Wax bars  D. Directs pesticide onto weeds but has a barrier that keeps the pesticide from contacting the crop.
5. Chemigation equipment  E. Ropes, rollers, or pads soaked with pesticide rub against weeds but do not contact crop.

A. 1–B, 2–D, 3–E, 4–C, 5–A