PUBLICATION 1482

FIELD SPRAYERS

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TIPS FOR SUCCESSFUL SPRAYING

Follow directions. Read the instructions and take the precautions printed on container labels.

Protect your eyes. Avoid inhaling chemicals and exposing your skin to them for long periods. Wear the protective clothing and masks that are recommended on the pesticide labels.

Post the telephone number of the closest Poison Control Center and the name of the pesticide being used beside your telephone.

Avoid spray drift. 2,4-D and related herbicides may seriously damage sensitive crops such as grapes, tomatoes, turnips, sugar beets, beans, carrots, tobacco, fruit trees, and ornamental plants. Use at least 10 gallons of spray solution per acre (110 litres/ha) and apply it at the lowest pressure at which the nozzles operate properly. Use the amine or low-volatile ester formulations to reduce vapor drift. Spray only when the velocity of the wind is less than 10 miles per hour (16 km/h).

Do not apply mixtures of different herbicides, or mixtures of herbicides and foliar fertilizers, insecticides, or fungicides in a single application unless this procedure is recommended on the label or by a competent authority.

Use equipment designed for the job.

Calibrate sprayers at least once a year and oftener if you are using wettable powders. Always operate at the calibrated speed and pressure.

Replace worn nozzles, defective hose, and a broken pressure gauge promptly.

Clean sprayers thoroughly after each use to prevent corrosion.

Preferably use one sprayer for herbicides and another for other pesticides. Otherwise, decontaminate the herbicide sprayer if you must use it for spraying an insecticide or fungicide on or near a herbicide-susceptible crop.

Use different handgun hoses for herbicides and for other pesticides.

Store herbicides away from other pesticides, seed, and fertilizer. Label partly empty containers as dangerous, and dispose of empty ones safely. Keep all containers away from children and animals.

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FIELD SPRAYERS

Chemicals are widely used on the farm to control weeds, insects, and diseases. The effectiveness of the pesticide (herbicide, insecticide, or fungicide) depends on:

Use of the proper chemical

Application of the chemical at the recommended rate and at the proper time

Proper use of the right type of application equipment.

This publication contains information on hydraulic field sprayers, their component parts, and how to use them efficiently. There are sections on three adaptations commonly used on Canadian farms, sprayer mounts, and operation of the sprayer.

Consult your local agricultural authorities or obtain publications from government or other sources on what chemicals to use for the control of weeds, insects, or diseases.

NOTE: Metric measurements given in this publication do not correspond exactly with examples in the common (British) system, because tank sizes, nozzle spacings, and so forth are not equivalent. Examples in the two systems should therefore be considered as different, although they are very similar.

TYPES OF SPRAYERS

FOG GENERATORS, also called aerosol generators, disperse chemicals in a fine airborne fog. These machines are used to control mosquitoes and flies in large buildings, parks, or similar areas. Fog generators are not usually used on a farm.

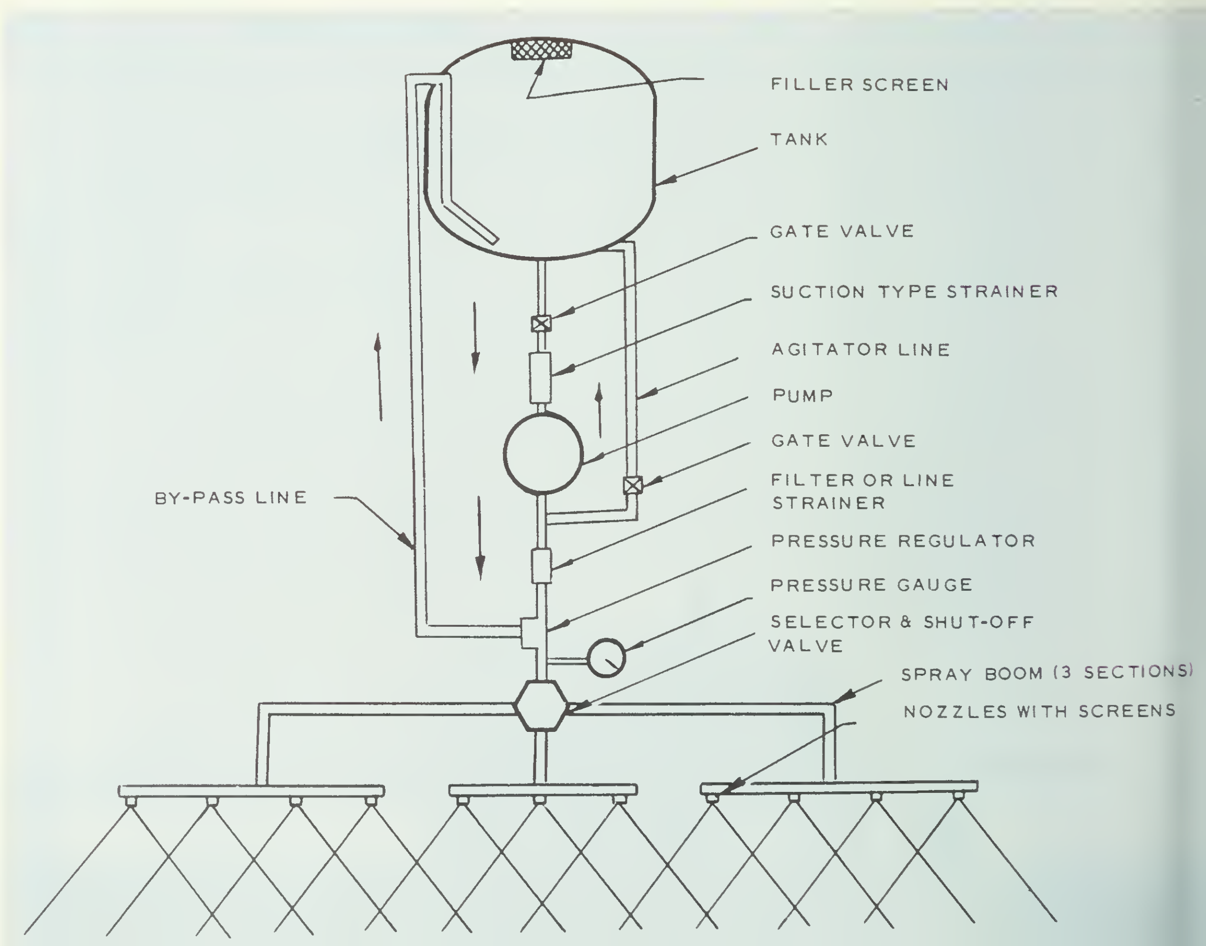
AIR-BLAST SPRAYERS dispense pesticides into a high-velocity air stream. They are generally used for spraying orchards, large numbers of shade trees, and some vine and vegetable crops. Sprayers of this type have been used in some areas for spraying row crops such as potatoes, and to a limited extent for field spraying of chemicals other than herbicides.

COMPRESSED-AIR SPRAYERS use air under pressure to force a liquid through a nozzle. An example is the small hand sprayer used around the farmstead and for spot spraying in the field. Large compressed-air sprayers are not common.

HYDRAULIC SPRAYERS dispense chemicals in a solution, in emulsions, or as wettable-powder suspensions. Water is the most common carrier for the chemical, and a pump delivers the liquid under pressure to one or more nozzles. Hydraulic sprayers are available with various types of tanks, pumps, nozzles, screens, controls, and other components. The type of equipment on the sprayer will determine the usefulness for applying the various pesticide formulations that are available.

The essential components of a hydraulic sprayer are illustrated in Figure 1.

FIGURE 1. The correct arrangement of sprayer components. Mechanical agitation is an alternative to hydraulic agitation.



BIVERT SPRAYERS are used to apply herbicides in the form of a multiphase invert emulsion. The positive-displacement-type pump draws a metered quantity of water and herbicide from one tank and a metered quantity of oil and emulsifier from a second tank. The metered quantities of water, herbicide, oil, and emulsifier are mixed in a mixing chamber on the suction side of the pump. The thick mayonnaiselike emulsion of water and herbicide suspended in oil is then pumped through the boom to special nozzles. Bivert emulsion sprays, which are claimed to reduce spray drift, are currently used for spraying roadsides and public-utility and railway rights-of-way. Bivert sprayers are not in common use on Canadian farms.

SPRAYER COMPONENTS

The parts mentioned in this section are common to all hydraulic sprayers.

TANKS

A tank must resist chemical corrosion. Steel tanks rust and corrode readily and need considerable care. Galvanized-steel tanks give reasonably satisfactory service if they are properly cared for but may eventually corrode. Aluminum or aluminum-alloy tanks weigh less than steel tanks and resist corrosion by most agricultural chemicals. Lightweight fiber-glass tanks resist corrosion by many chemicals, including herbicides, insecticides, fungicides, most acids, and solutions of the salts of most acids. Stainless-steel tanks and steel tanks with a special baked-on factory finish resist corrosion by practically all agricultural chemicals. A 45-gallon (205-litre) drum is the least expensive sprayer tank. When the drum is mounted in a vertical position, the return line from the pressure regulator (see Figure 1) should deliver the liquid to the bottom of the drum. Ordinary steel drums rust and corrode rapidly, their openings normally are too small to permit a wettable powder to be added conveniently, and their design makes proper agitation of a wettable-powder suspension almost impossible.

The choice of the sprayer tank depends on the chemicals that are to be handled and the initial cost; a low-cost tank is seldom a good investment. Corrosion and rust cause plugging of strainers, screens, and nozzles; excessive pump wear; and the eventual ruin of the tank.

Construction of the tank affects sprayer operation and care. The opening should be at least 12 inches (30 cm) across, splash proof, and equipped with a coarse screen. The cover should be vented and sealed against dust. A large opening facilitates filling and cleaning. The drain plug should be located so that the tank can be completely drained for frost protection and for flushing out sediment. The return-flow pipe normally discharges into the lower portion of the tank. This helps to prevent excessive foaming of the solution. The suction-pipe intake should be near the bottom of the tank but not too close to the return-flow pipe. It is easier to provide satisfactory agitation of spray material in a tank with a round bottom than in one with a flat bottom and square corners.

PUMPS

Pumps vary considerably in capacity, operating speed and pressure, and resistance to corrosion and wear. It is best to consider the manufacturer's recommendations when you select a pump for a sprayer. Pump capacity is affected by speed and, for most pumps, by the operating pressure. The capacity must be great enough to handle jobs requiring an unusually high application rate. The pump must supply liquid under pressure for hydraulic agitation if the sprayer is not equipped with a mechanical agitator. When selecting a pump, consult the manufacturer's performance tables or charts and allow for about 25 percent reduction in capacity because of wear.

The pump may be driven by a tractor PTO or by an auxiliary engine. An auxiliary engine should have enough reserve capacity to operate the pump at maximum pressure and also a mechanical agitator when needed. Late-model tractors have a choice of PTO speeds.

CAUTION: Most positive-displacement-type pumps (gear, roller, diaphragm, and piston) are not designed to operate at the 1,000-rpm PTO speed used on some tractors. Follow the pump manufacturer's recommendations.

The GEAR PUMP (Figure 2) is useful for some types of low-pressure spraying. It is inexpensive, but it wears rapidly if operated continuously near maximum pressure. Do not use brass gear pumps with abrasive materials such as wettable powders. Some gear pumps are made of sufficiently durable materials to handle wettable-powder suspensions. Check manufacturers' recommendations before using gear pumps for abrasive materials.

The ROLLER PUMP (Figure 2) handles a wide range of agricultural chemicals if properly equipped. The type equipped with nylon rollers mounted in a special rust-resistant, cast-iron case works well with most sediment-free agricultural chemicals. Rubber rollers are intended for pumping water and are considered suitable for pumping wettable powders. Abrasive materials (most wettable powders, derris, and sulfur mixtures) shorten the service life of a roller pump. The pump housing, the roller slots in the rotor, and the rollers are all worn by abrasive materials. Replacing the rollers may not restore the pump to a serviceable condition.

The DIAPHRAGM PUMP (Figure 3) has been adapted for sprayer use in recent years. The pump is driven by the PTO of a tractor and develops pressures of up to 130 psi (900 kPa *). It gives excellent service with abrasive materials and is well adapted for general sprayer use where pressure and volume are not limiting factors.

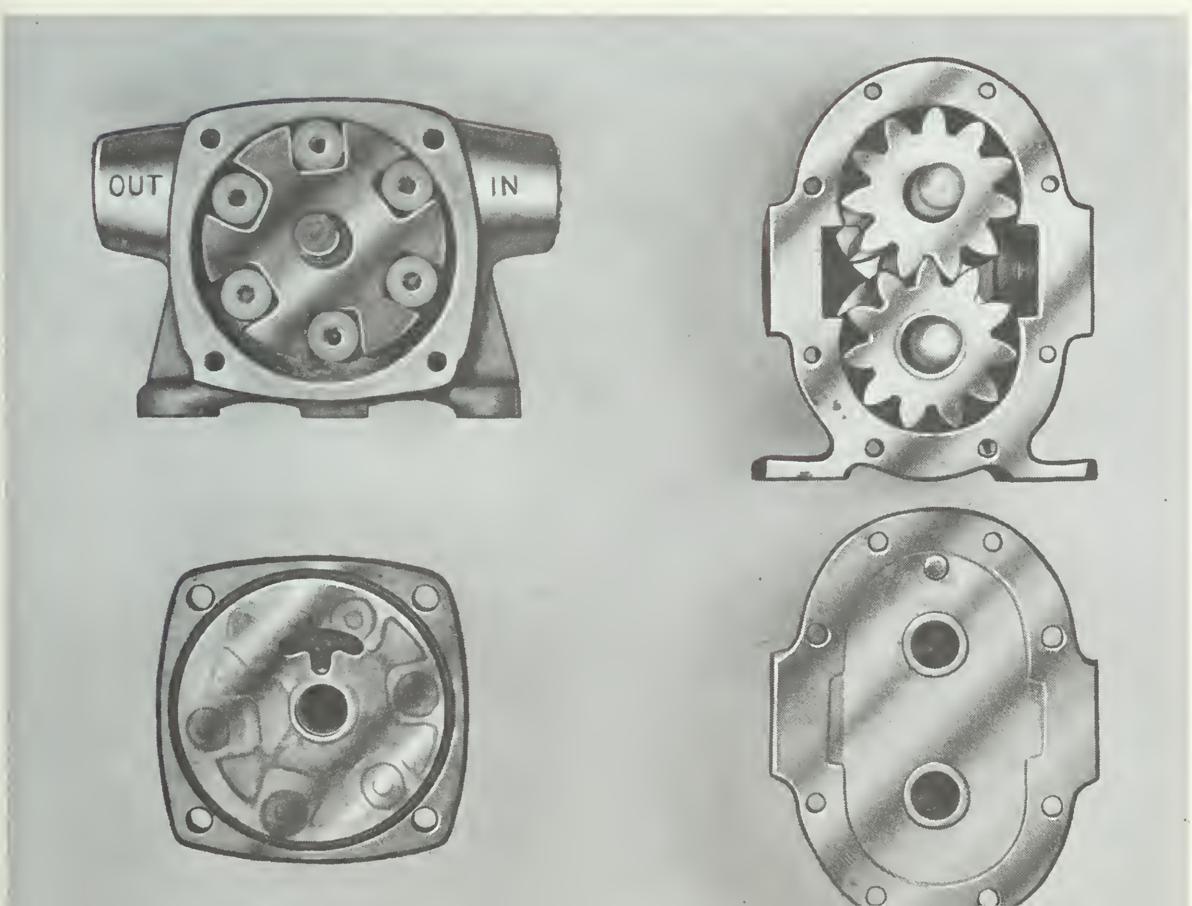
The PISTON PUMP is commonly used on high-pressure sprayers but may also be used at low pressures. A radial 4-cylinder piston pump, usable at any pressure up to 500 psi (3,450 kPa), has been developed for direct PTO drive as well as for auxiliary-engine drive (Figure 15). Small single- and twin- cylinder piston or plunger pumps (Figure 4), which develop pressures of up to 500 psi (3,450 kPa), have also been adapted for use with a tractor PTO. Some multicylinder pumps are limited to speeds of 200 rpm or less (Figure 16). Piston pumps should not be driven at a speed faster than the manufacturer recommends.

Piston pumps designed for use on sprayers are usually equipped with abrasion-resistant cylinder liners, valves, and seats and with nylon fabric or leather piston cups. These pumps will handle a very wide range of agricultural chemicals, including abrasive wettable powders.

Piston pumps are equipped with either an internal or an external air chamber. A chamber is necessary to dampen pulsations in the liquid flow. A piston or plunger pump, although more expensive than other types, is a sound investment if the sprayer must be used for a variety of spraying operations.

* See "Glossary."

FIGURE 2. *Left*, a roller pump, *right*, a gear pump.



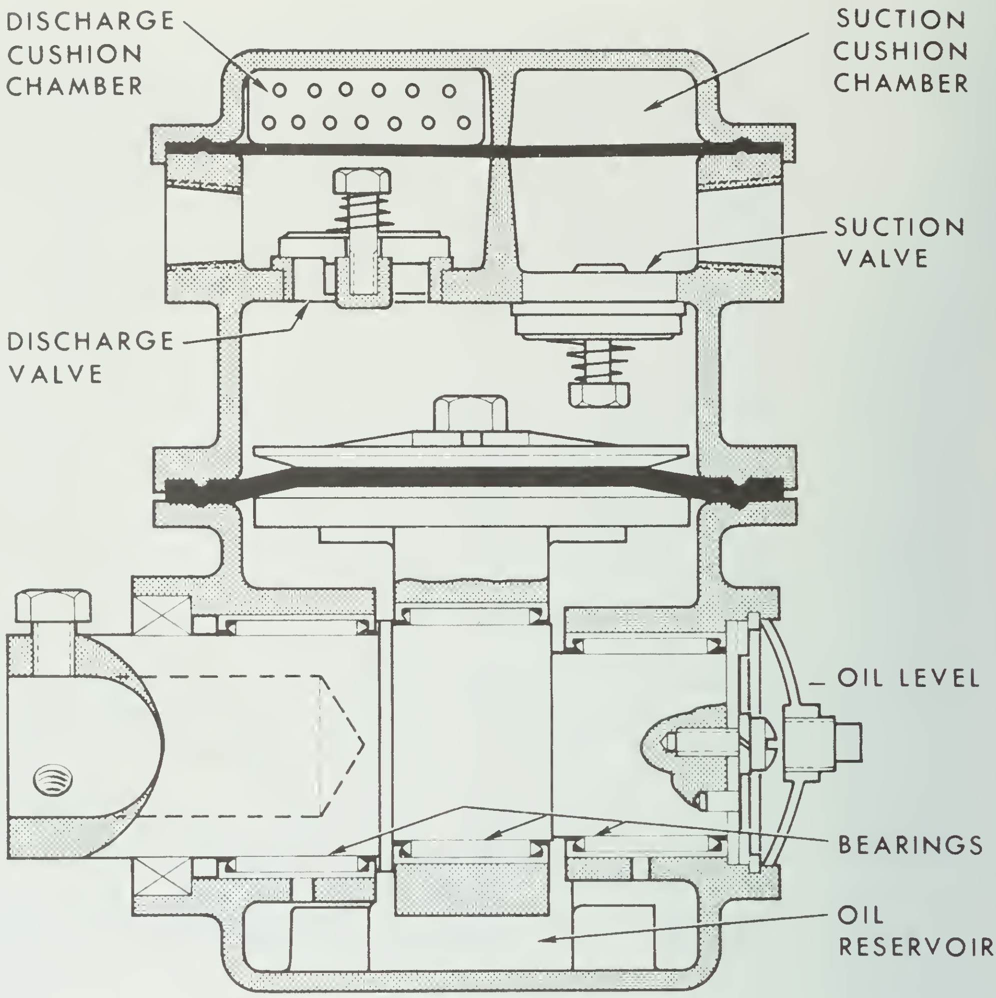


FIGURE 3.
A diaphragm pump.

CAUTION: All pumps of the positive-displacement type must be operated with a bypass pressure regulator. Do not use a hand valve or tap to control pressure.

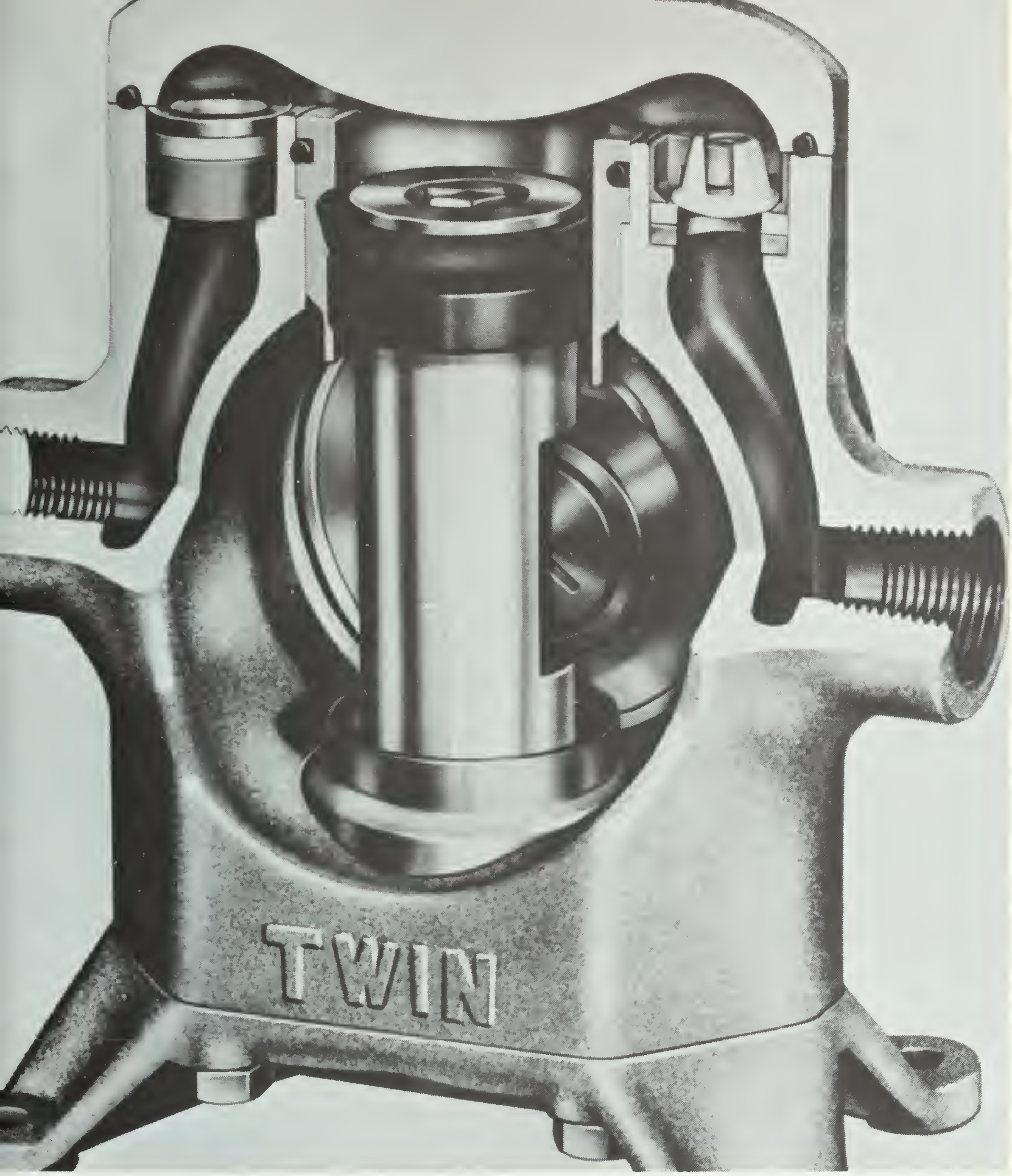
The CENTRIFUGAL PUMP (Figure 5) is the only pump of the types commonly used for sprayers that does not displace liquid positively. The single-impeller centrifugal pump must be operated at a high speed (3,000 to 6,000 rpm) to obtain the capacity needed for spraying. Gears built into the housing allow the pump to be operated from the PTO of a tractor.

The centrifugal pump is not self-priming, therefore it must be mounted below water level or a priming system must be used. Most centrifugal pumps resist abrasion and are claimed to handle wettable powders satisfactorily for years.

CAUTION: Never allow a sprayer pump to run dry. Rollers, seals, bearings, or all of them, may be severely damaged.

FIGURE 4. A piston or plunger pump

FIGURE 5 A centrifugal pump mounted directly on a tractor PTO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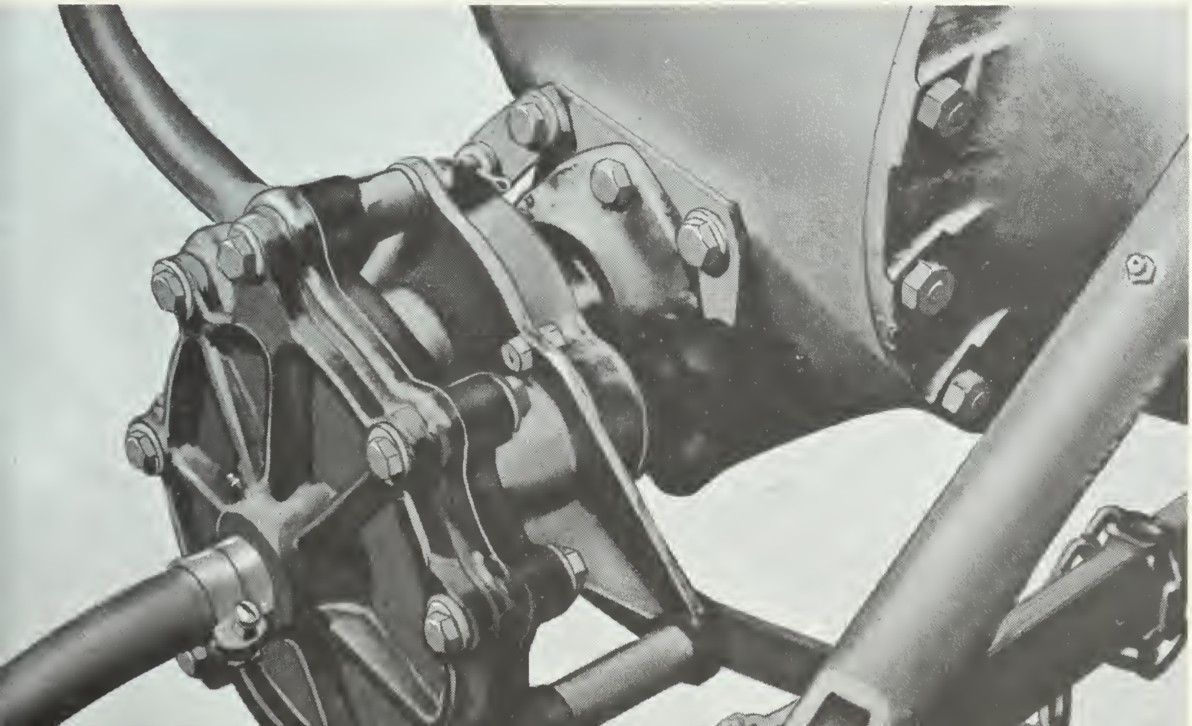


NOZZLES

Nozzles (Figure 6) are manufactured for a wide range of application rates and crop conditions. Performance tables are available from most dealers; consult these tables when selecting nozzles (see "Control of Sprayer Output").

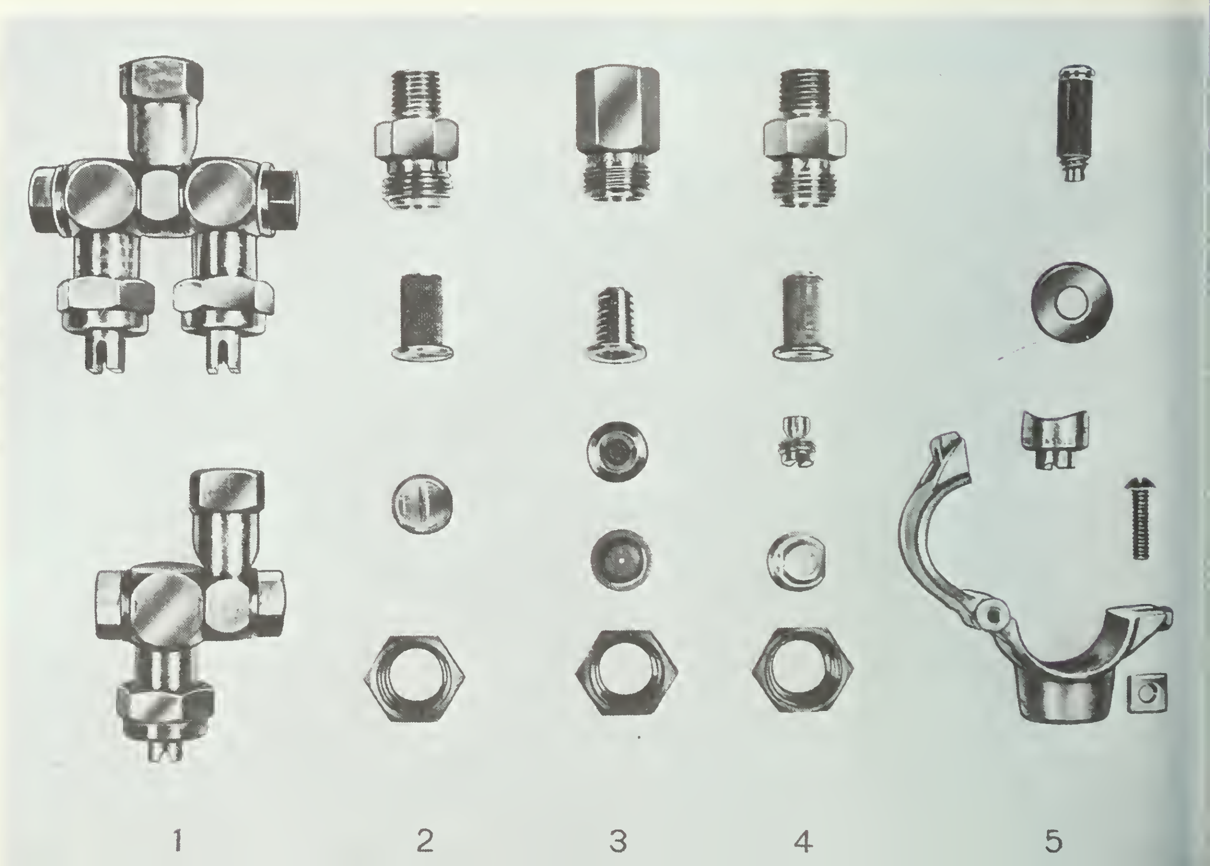
Nozzle bodies are available with either male or female thread connections; others have clamp-on connections, which are frequently used with aluminum or brass booms and are readily removed for cleaning and inspection. Nozzle tips or discs of various sizes are interchangeable in most bodies.

Nozzle tips are manufactured from several materials. Generally, plastic tips resist wear better than brass or aluminum tips. Ceramic, stainless-steel, hardened stainless-steel, and tungsten-carbide tips resist wear longer than the other types.

CONE NOZZLES (Figure 6) are used mainly on row-crop sprayers for applying insecticides and fungicides. The nozzles operate best at a pressure of about 80 psi (550 kPa), but higher pressures can be used if needed. Some nozzles produce a hollow-cone pattern and are used for low-volume applications where a fine spray is needed for thorough plant coverage. Others produce a solid-cone spray pattern and are used for high-volume applications where dense foliage requires a penetrating spray. Cone nozzles can be used to apply wettable powders.

FAN NOZZLES are commonly used on field sprayers and may be used on row-crop sprayers (see "Row-crop Sprayers"). Fan nozzles produce tapered-edge spray patterns, which give reasonably uniform coverage if properly overlapped. The usual fan angles are 65, 73, and 80 degrees.

FIGURE 6. Nozzle components: 1, double and single-swivel bodies equipped with off-center tips; 2, flat-fan tip; 3, hollow-cone orifice disc and core; 4, full-cone tip and threaded core; 5, clamp-on nozzle (screen, gasket, flat-fan tip, and body). Nozzle bodies (male or female 1/4- or 1/8-inch pipe thread), screens (coarse mesh, slotted, and fine mesh), and caps in assemblies 1, 2, 3, and 4 are interchangeable.



Nozzles with angles greater than 80 degrees are manufactured for some sprayer uses. The angle of delivery varies slightly with pressure and governs the spacing of the nozzles on the boom. Most fan nozzles used for full-coverage field spraying function best at pressures of about 30 psi (205 kPa). The proper alignment of fan nozzles on a field boom is shown in Figure 10. When nozzles made from various materials were used on a 13-nozzle boom to apply a wettable powder at 90 psi (620 kPa), the output from brass nozzles increased by 25 percent after spraying 100 acres (40 ha). The relative wear resistance of 80-degree fan nozzles made of various materials compared with brass nozzles was as follows:

brass	1
plastic	3
stainless steel	19
hardened stainless steel	77

The steel nozzle tips usually cost three to four times as much as brass. Obviously, when abrasive materials are to be sprayed, the wear-resistant nozzle tips are a good investment.

FLOODING FAN NOZZLES provide a wide-angle (up to 135 degrees) flat spray that is useful for low-pressure spraying. Application volumes are higher than those used for some pesticide spraying. These nozzles are normally used for applying liquid fertilizers or herbicides, or both, that may have to be immediately incorporated into the soil. Recent experimental work indicates that a drift-resistant herbicide spray may be produced when flooding fan nozzles are angled about 10 to 15 degrees in the direction of travel.

EVEN-SPRAY FAN NOZZLES are designed to provide uniform distribution within the spray pattern from each nozzle. They usually provide a spray with a fan angle of 80 degrees and are designed only for the band application of chemicals to row crops.

JET NOZZLES project a curtain of spray in a wide arc for a considerable distance. One type, the off-center boom extension nozzle, is sometimes used on the ends of a field boom to extend coverage by 5 feet (1.5 m) or more at each end. They should be chosen to provide the same spray rate as the other nozzles on the boom.

MULTIPLE-ORIFICE NOZZLES, or clusters of nozzles, are used in place of a boom and spray a swath about 30 feet (9 m) wide. The rate of application depends on the width of the swath (as determined by the spray angle and the height of the nozzle), the liquid pressure, the orifice size, and the speed of travel. These nozzles are best used for spraying roadsides, ditch banks, rights-of-way, and other places where the use of a field or row-crop boom sprayer is unsatisfactory.

AGITATOR NOZZLES (Figure 7) may be used in the spray tank to keep wettable-powder pesticides in suspension. Hydraulic agitation is effective only if nozzles are placed in the bottom of the tank and are supplied directly from the pump. Jet agitator nozzles that use orifice plates to project a stream of liquid are suitable for small spray tanks. Large-volume jet agitator nozzles with siphon caps should be used

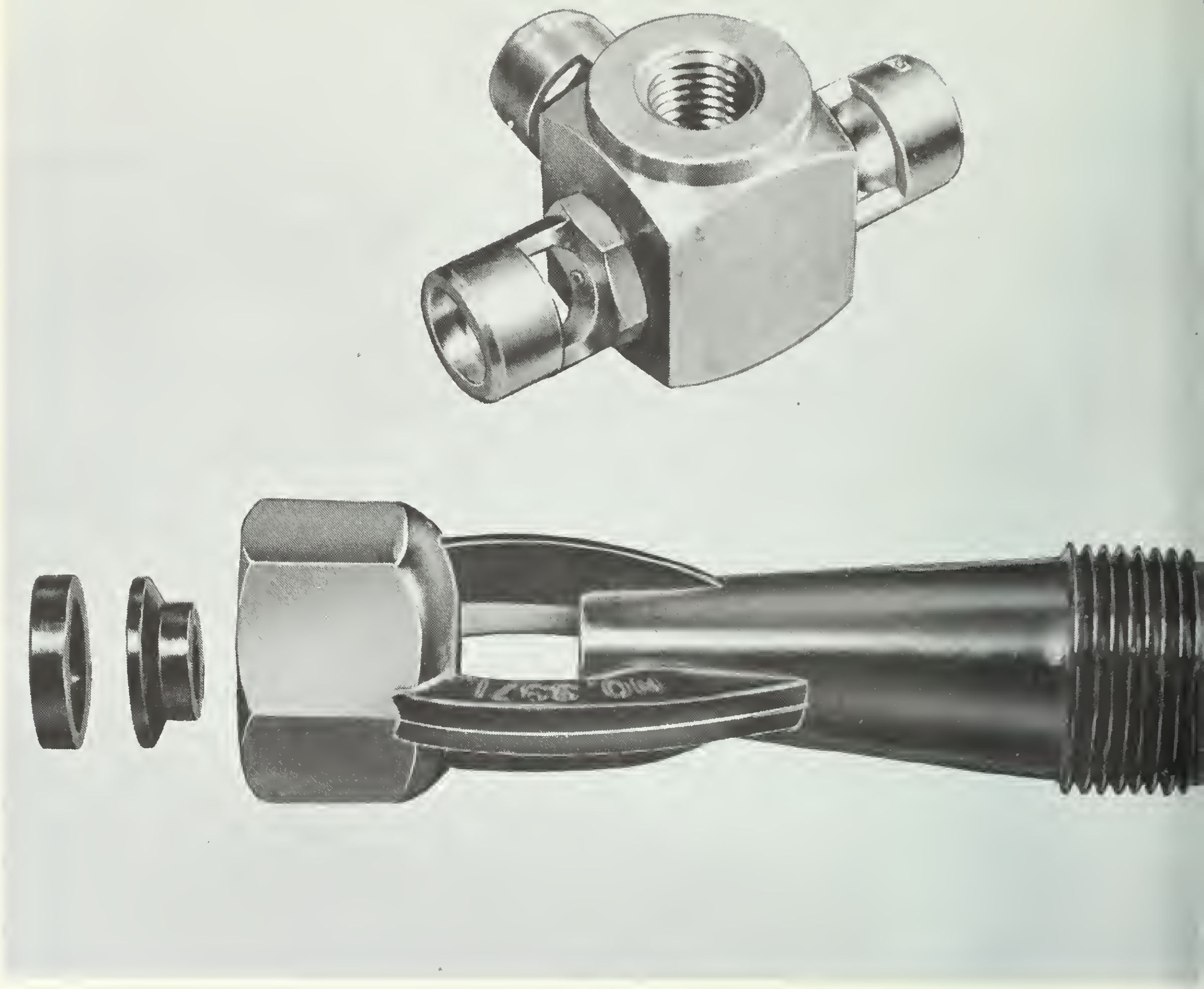


FIGURE 7. Agitator nozzles.

in tanks of greater capacity than 100 gallons (455 litres). With nozzles of this type the liquid is projected in a solid stream through the center of the siphon cap. The siphoning action draws in liquid and creates strong swirling currents to agitate the liquid in the tank. The total volume of liquid projected through the siphon cap is about three times the amount supplied to the nozzle.

Agitator nozzles are available in brass, stainless steel, aluminum with stainless-steel caps, and nylon. Wear resistance is a major consideration when purchasing these nozzles. Nozzles must be solidly mounted in the tank to prevent whipping. The pump must be able to supply liquid for the boom, the agitator line, and the bypass return line (see "Agitation" and "Control of Sprayer Output").

SCREENS

Screens remove foreign material that might clog nozzles, wear pumps, and interfere with the operation of valves and controls. They must be accessible for cleaning.

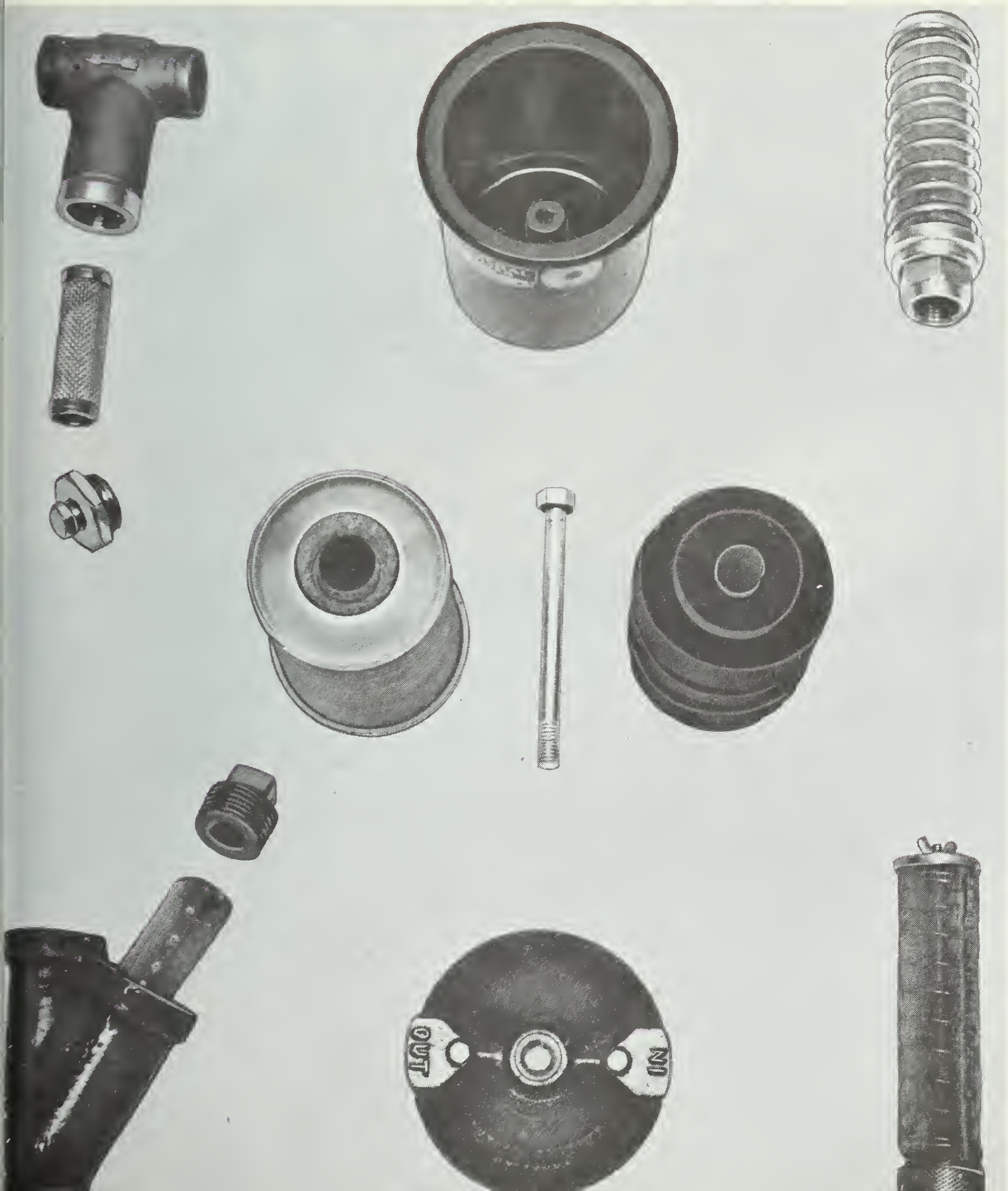
The line strainer (Figure 8) is usually in the line between the pump and the tank. Filter elements are frequently used in place of screens where water supplies contain fine suspended silt.

The screen at the nozzle must have openings smaller than the nozzle aperture. Interchangeable nozzle screens come in mesh sizes from 20 to 200, which refers to the number of holes per lineal inch of screen (8 to 80 holes per centimetre). The nozzle screen has a small surface area and plugs quickly if the line strainer is not functioning properly.

A slotted strainer (Figure 6) often is used at the nozzle to prevent the buildup of suspended solids when wettable powders are applied by nozzles with a high delivery rate.

When nozzle dribble may cause crop damage, use a nozzle screen with a check valve in it. Nozzle dribble occurs when the boom is shut off. The check valve prevents dribble but does not interfere with the operation of the sprayer. Extra care must be taken, when cleaning a nozzle screen having a check valve, to remove any formation of gum or accumulation of powder that would prevent the proper operation of the check valve.

FIGURE 8. Strainers. *Left* screen types; *center*, large-capacity Monel Metal screen or replacement filter element for use in the line between the pump and the boom; *right*, two types of suction strainers.



CONTROL VALVES

Sprayer controls (Figure 9) should be within easy reach of the operator. A selector shutoff valve that controls output to one or all sections of the spray boom is useful.

REGULATORS

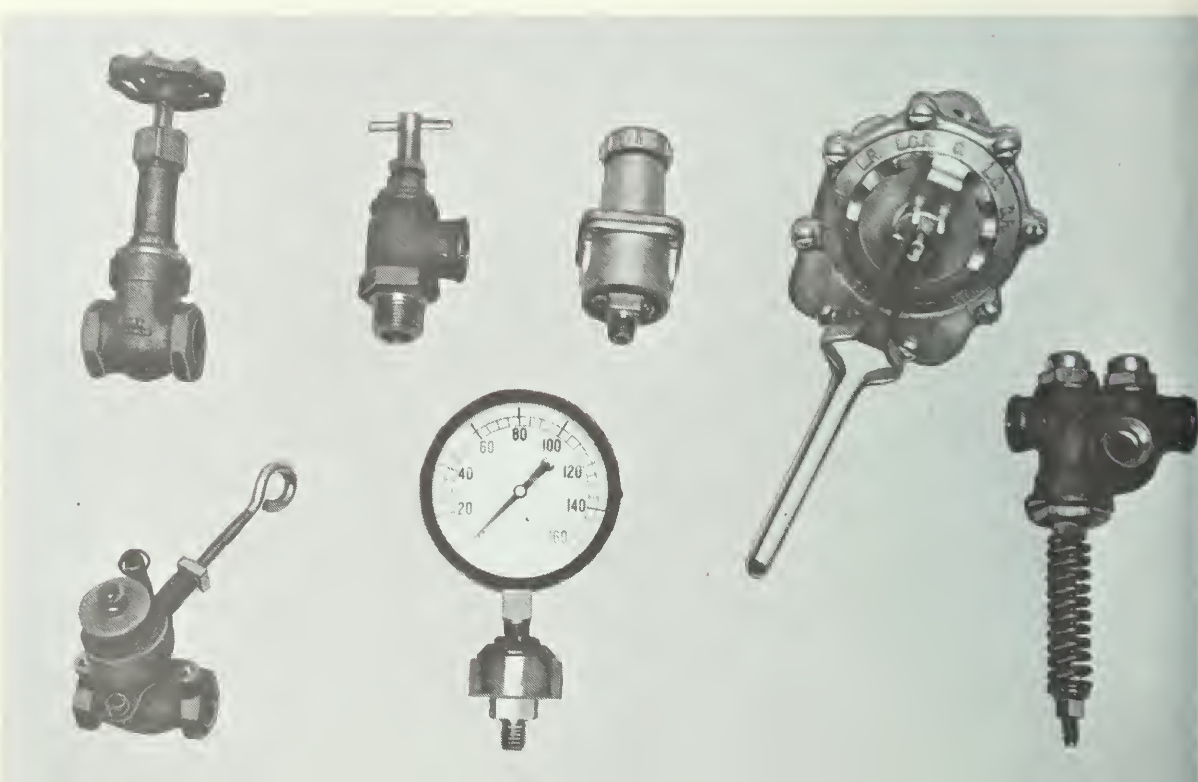
The pressure regulator provides a means of adjusting pressure, within the limits of the pump. The relief-valve regulator, which bypasses excess fluid to the tank, is commonly used on low-pressure sprayers. When the boom is shut off, the bypass pressure regulator allows the total output of the pump to return to the tank. This usually increases the pressure in the bypass line, especially if the bypass hose is too small; ½ inch (13 mm) is the minimum recommended hose size.

The unloader type of regulator is used on high-pressure sprayers. This valve bypasses excess liquid during operation and, when the boom or handgun is shut off, returns all liquid to the tank at a very low pressure. The unloader regulator is a definite asset on sprayers powered by an auxiliary engine and on sprayers equipped with a piston or plunger pump.

PRESSURE GAUGE

The gauge is mounted on the output side of the pump to provide the operator with a visual guide in controlling pressure. Accurate pressure control is essential for the proper application of pesticides. A damaged or broken gauge should be replaced with a good-quality unit calibrated over the pressure range of the pump.

FIGURE 9. Sprayer controls. *Upper left to right*, gate valve, spring-loaded ball-check pressure regulator, diaphragm-type pressure regulator, and selector shutoff valve; *lower left to right*, rope-controlled boom shutoff valve pressure gauge with diaphragm-type surge dampener, and unloader-type pressure control valve.



HOSES

Sprayer hoses convey liquid under high pressure. Surging in the line, caused by shutting off the boom, can increase the hose pressure considerably above the operating pressure. Always use hoses rated for higher than the maximum pressure the sprayer pump will supply. The size of hose is important. If the suction hose is too small, the pump will be starved. If the pressure hose is too small, the system must work under extra pressure, and nozzles at the boom ends may be starved. Always replace any hose with a size at least equal to that supplied with the sprayer and never a smaller size.

BOOM-TYPE SPRAYERS

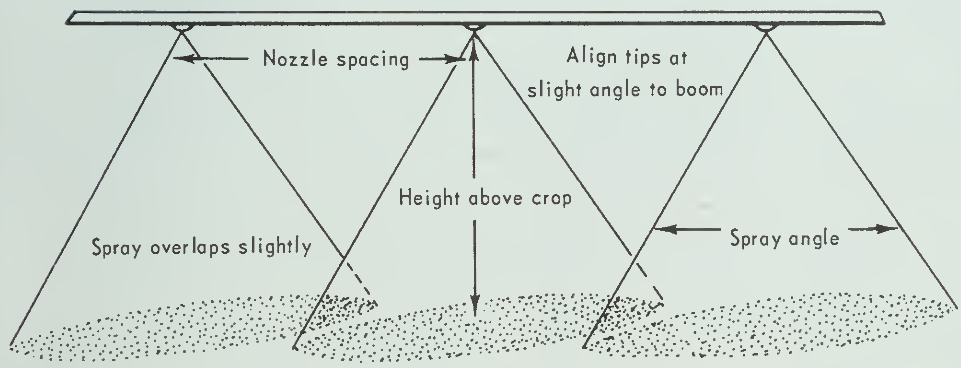
The boom-type sprayers are usually equipped for low-pressure work, but some are designed for high-pressure spraying. The low-pressure sprayer is best suited for applying sediment-free chemicals to a field crop.

The sprayer is normally equipped with a tank, a pump, controls for pressure regulation with bypass agitation of material in the tank, screens, hose lines, and a boom. A handgun is a useful accessory.

A boom-type sprayer should meter the correct amount of the spray material and distribute the spray in a suitable pattern (Figure 10) across the swath. The application rate is determined by ground speed, nozzle spacing, nozzle size, and operating pressure (see "Control of Sprayer Output"). A good spray pattern consists of a large number of small droplets of uniform size, closely spaced and evenly distributed across the swath. The spray pattern is influenced by the type of nozzle, operating pressure, boom height, and operating conditions.

The SPRAY BOOM carries the solution to nozzles spaced along the boom. It is usually hinged to fold upward or rearward for transport. Most booms swing back under heavy impact to protect the boom from damage.

IGURE 10. A section of a field boom showing proper adjustment of ıe fan-type nozzles to provide overlap of spray.



Most spray booms are made of aluminum or copper, both of which resist corrosion. Others have a special baked-on factory finish that resists corrosion.

The field boom is usually equipped with fan nozzles, spaced 20 inches (50 cm) apart, that deliver 5 to 30 gpa when the sprayer is operated at a speed of 4 to 5 mph and a pressure of 30 to 40 psi (55-330 litres/ha at a speed of 6-8 km/h and a pressure of 205-275 kPa). Some pesticides are applied with more than 30 gpa (330 litres/ha) of water and require different nozzles (see "Control of Sprayer Output").

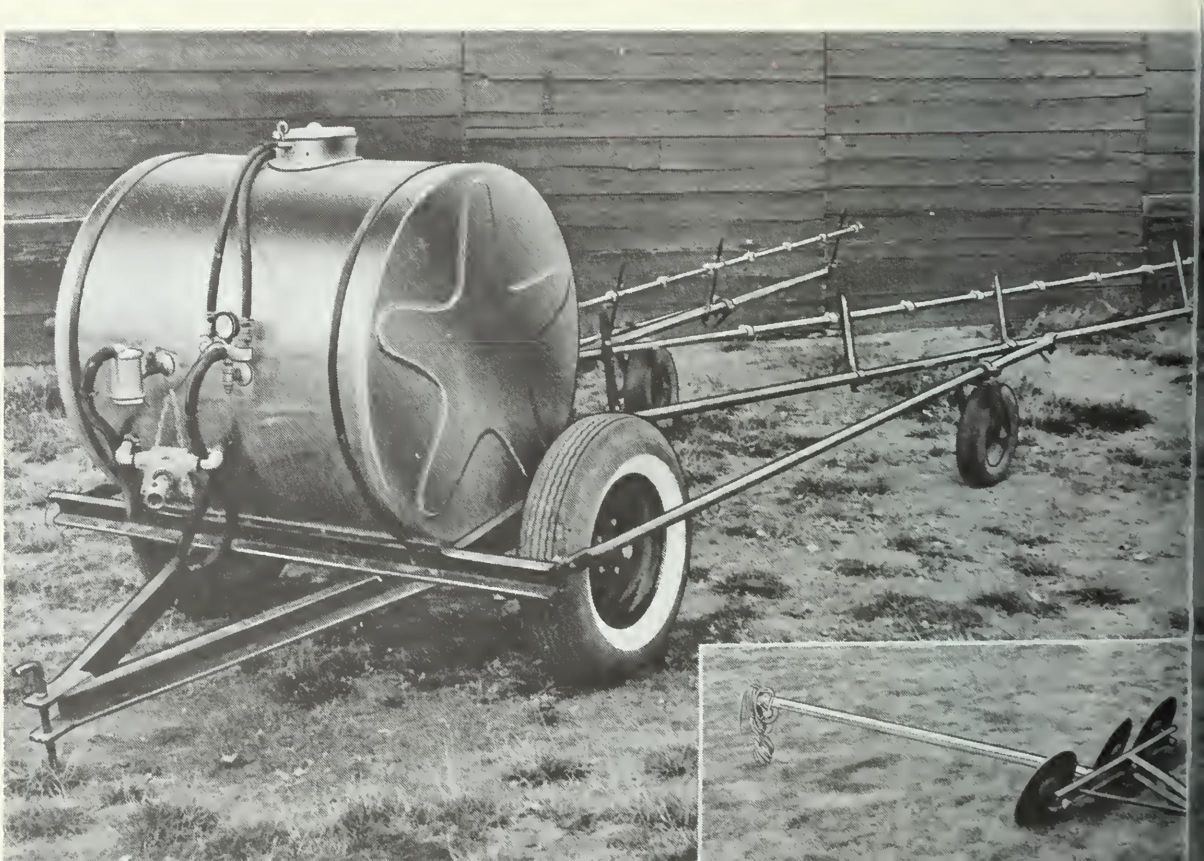
The boom must have enough support; the longer it is the more support it needs. A boom longer than 30 feet (9 m) should be supported by outrigger wheels and tie rods (Figure 11). These help to keep the boom at a uniform height, particularly on rough or rolling land.

BOOM WHIP is a problem with long booms. Vertical and horizontal boom whip occurs on uneven ground, particularly when the boom is not well supported. The spray pattern becomes distorted, and some parts of the swath receive a heavy application while others receive a light one. Excessive boom whip is almost certain to cause poor control of the application rate. Excessive vertical whip can cause boom ends to hit the ground, thereby damaging the boom and producing misses in the spray pattern.

To prevent boom whip, add extra braces. On long booms use castor wheels with good tie rods. Always pin the tractor drawbar, because this helps to eliminate horizontal whip. When you buy a sprayer, make certain that the boom is adequately braced and supported.

The BOOMLESS SPRAYER should not be used for field spraying (see "Nozzles"). This type of sprayer has a single nozzle or cluster of nozzles instead of a field boom.

FIGURE 11. A low-pressure trailer-mounted boom-type sprayer with outrigger wheels and tie rods to support the boom. *Inset*, one type of field marker.



The spray near the nozzle has a closely knit pattern of fine drops, whereas the outer edges of the spray have an open pattern of large drops. This variation can result in poor spray distribution. Wind upsets the spray distribution from the boomless sprayer more than from the boom sprayer.

CAUTION: Never use a boomless sprayer when there is any danger of spray drifting on to susceptible crops.

The FIELD MARKER (Figure 11) makes a guideline that helps the operator to avoid overlaps and skips between rounds. The marker is attached to the field sprayer with a rope or cable. The length of the rope is adjusted to control the position of the marker.

The marker is essential for good field spraying. Use it on all open-field spray·work.

Another type of marker using a foam has proved useful on golf courses and other areas where the soil surface should not be disturbed. The tractor exhaust supplies the power to generate the foam and deliver it to the special nozzles mounted on both ends of the boom.

ROW-CROP SPRAYERS

Row-crop sprayers (Figure 12) are either tractor-mounted or trailer-mounted (see "Sprayer Mounts"). The component parts are similar to those used on the boom sprayer, but the boom is designed to provide proper spray placement for row crops.

FIGURE 12. A trailer-mounted row crop sprayer. The trailer provides high frame clearance and adjustable wheel read. The drop pipes have flexible connectors to protect the nozzles from damage.

Most ROW-CROP BOOMS are for four, six, or eight rows. The length of the boom depends on row spacing and is usually not more than 28 feet (8.5 m). The boom has nozzles centered over each row and drop pipes between the rows. The lower end of each drop pipe has swivel connectors (Figure 6) and nozzles. Drop pipes used for tall crops also have one or more nozzles mounted along the pipe. This type is often called a corn-drop pipe. A flexible mounting protects nozzles and pipes from damage if they hit the ground.

Skid-supported drop pipes are used where one or more nozzles must be positioned close to the soil surface for accurate placement of the spray. The skid is hinged to the boom or sprayer frame and is held to the soil surface by gravity or by a coil spring or similar device. Accurate positioning of nozzles to place the spray under the leaves of crops in rows or on a band of soil between rows is called ***directed spraying***. If directed spraying is to be done properly, the crop plants should be of uniform height and the soil surface should be smooth.

Some row-crop booms are of the universal type. They are equipped with short lengths of spray hose leading to each nozzle and drop pipe. A system of clamps is used to position the nozzles on the boom accurately for various row spacings and for different heights of crop.

The choice of nozzle depends on the type of spraying to be done (see "Nozzles"). Use cone tips on row-crop sprayers to obtain complete coverage of the growing plant.

Use at least five nozzles per row (Figure 13) when spraying tall crops such as corn. Always use enough nozzles to cover the entire plant with a penetrating spray from the top and sides.

The BAND SPRAYER (Figure 14) is essentially a row-crop sprayer adapted to apply chemicals in a band. A nozzle is placed to treat a 6- to 12-inch (15-30 cm) band along or over each row. Even-spray nozzles are preferred for band spraying, but flat-fan nozzles can be used. Cone nozzles should not be used for band spraying. If wettable powders plug the nozzles, increase the application volume by using nozzles with larger orifices and coarser screens.

To apply chemicals in a band to the soil surface without incorporating them, mount an even-spray nozzle behind the planter press wheels, and adjust the nozzle height to spray a band of the desired width. Commercial band-spraying attachments are available from some planter manufacturers.

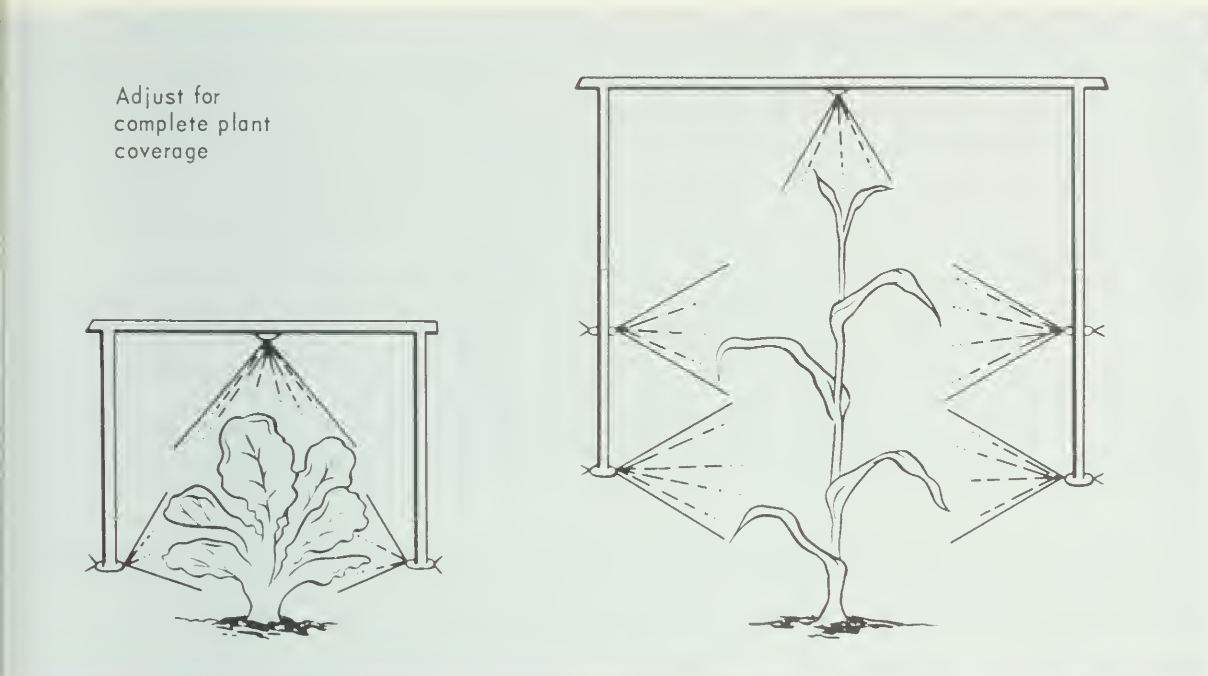
Some preplant chemicals need to be worked into the soil for best results. To incorporate the chemical into the soil mount a tiller unit on the tractor (Figure 14) and pull a row-crop planter behind the tractor to plant seed in the treated band of soil. Use press wheels on the planter to pack the loosened soil around the seed.

Rotary tillers of the row-crop type are used to mix chemicals into the soil. Power-driven units mounted on a tractor give good results. Commercially available units use a hood over each tiller unit to increase the mixing action.

FIGURE 13. Sections of row-crop booms showing nozzle adjustments when three nozzles and five nozzles are used for each row.

FIGURE 14. A band sprayer. One even-spray fan nozzle, mounted in front of each of the hooded power-driven rotary tiller units, treats a band of soil for each row. Press wheels in front of and behind each planter unit provide good seedbed conditions.

Rotary-hoe (rotary-weeder) attachments are made for many row-crop cultivators. Mount two units in tandem for each row, and offset the spider wheels on the rear unit to give an overall spacing of about 1½ inches (3.8 cm) between wheels. Reverse the spiders to provide a treading rather than a picking action. The soil and chemical may not mix properly



if the soil is very hard, too moist, or stony. Commercial band applicators that use the rotary-weeder principle are available.

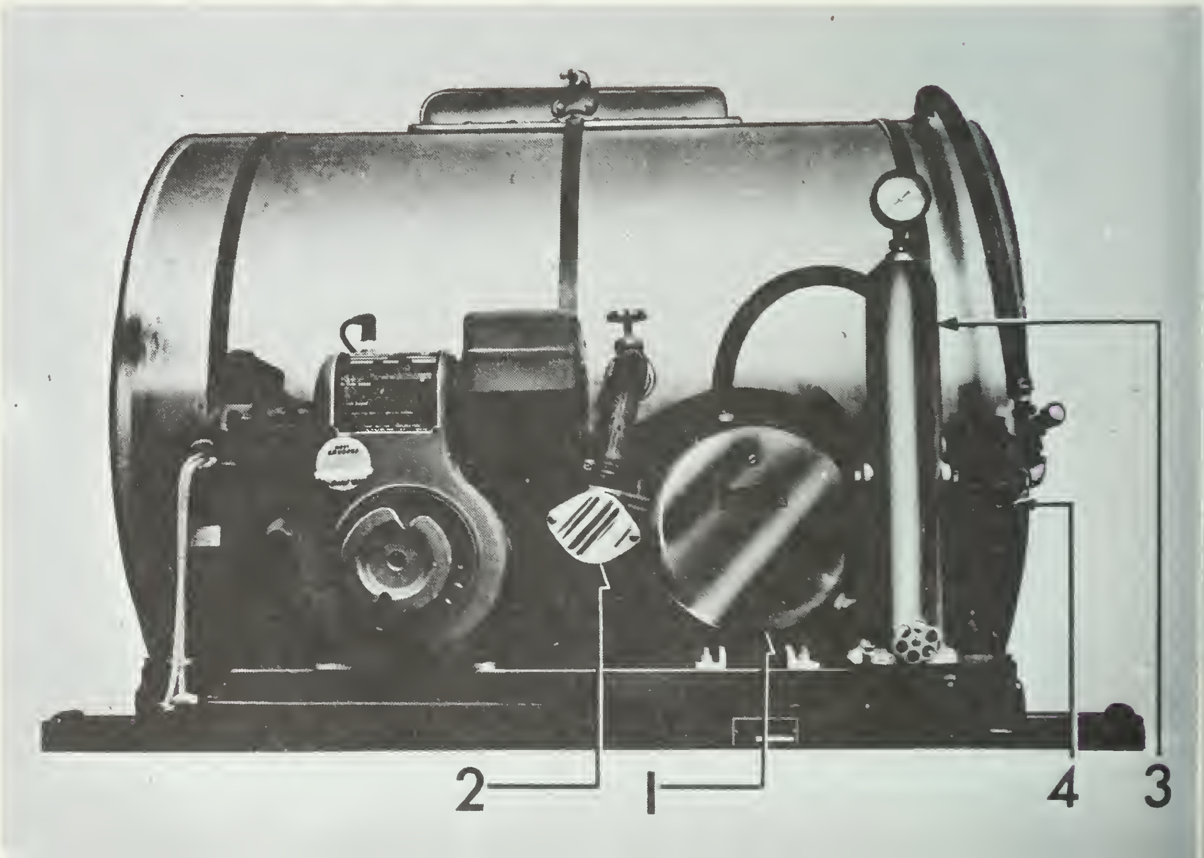
Various methods of soil incorporation for band spraying have been studied intensively. Where a pesticide requires thorough preplanting incorporation in the band, the hooded power-driven rotary tiller has given better results than the rotary-weeder or drag-harrow-type attachments.

Special HIGH-CLEARANCE ROW-CROP SPRAYERS are available in self-propelled models. The sprayer is equipped with a high-pressure pump and a row-crop boom. A field boom is also available. These sprayers have a clearance of over 5 feet (1.5 m) and are especially adapted for use in tall crops.

UTILITY SPRAYERS

Utility sprayers (Figures 15 and 16) are mostly used for high-pressure applications but can be used for low-pressure spraying if a low-pressure regulator is added. They are available in flat-bed, trailer-mounted, and tractor-mounted models (see "Sprayer Mounts"). The utility sprayer may be used to apply insecticides to livestock and to barns and other buildings. Trailer-mounted and tractor-mounted models, if equipped with a suitable boom, can be used for insect or weed control in field and row crops. The utility sprayer can also be used for spraying fence lines, ditch banks, and other out-of-the-way places. If you must use the herbicide sprayer for applying insecticides or fungicides, be very careful that crops are not damaged by herbicide residue left in the tank (see "Decontamination").

FIGURE 15. A utility sprayer: 1, radial 4-cylinder piston pump; 2, large-capacity line strainer; 3, surge chamber and gauge; 4, unloader-type pressure regulator. The tank is equipped with a mechanical agitator and with a large hatch-type opening for easy servicing



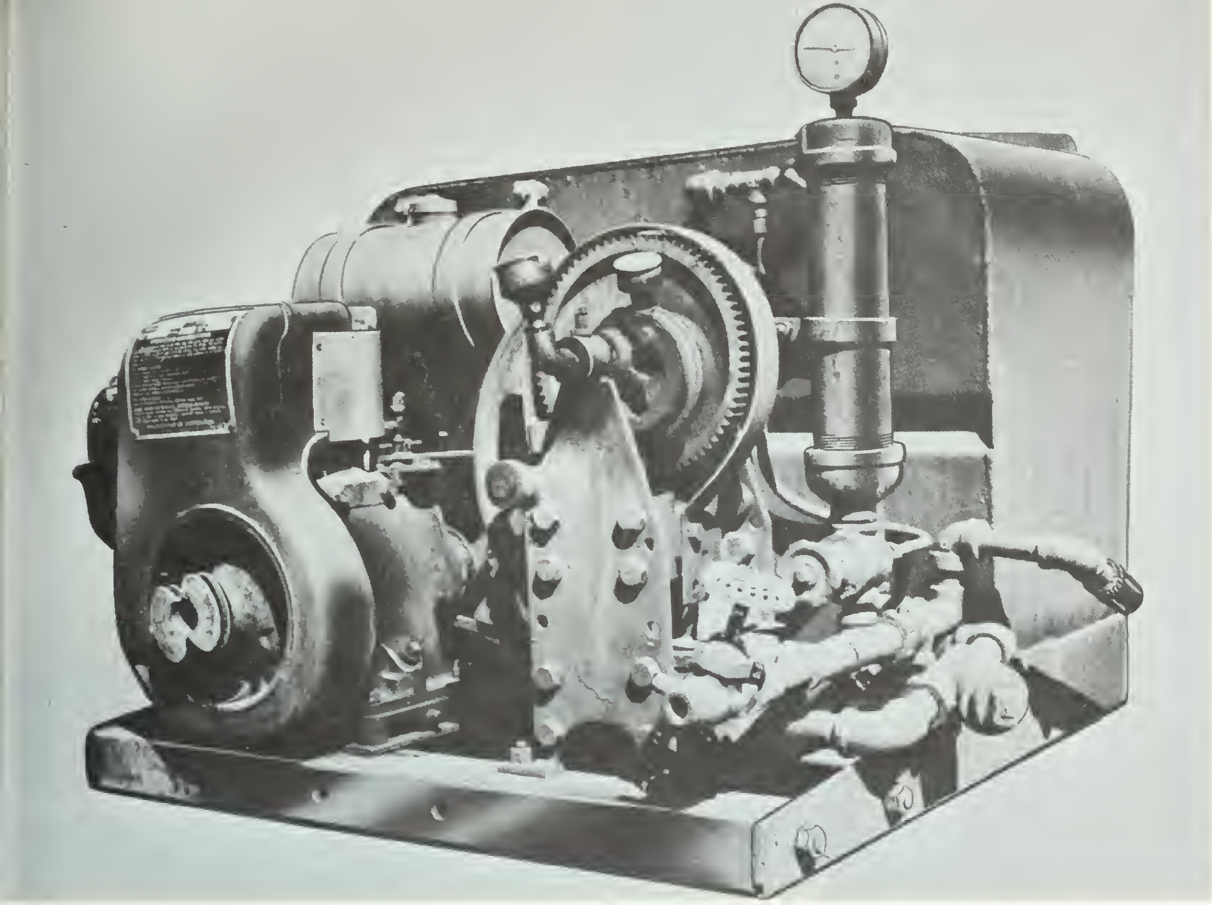


FIGURE 16. A utility sprayer. The twin-cylinder vertical piston pump, the surge chamber, the pressure regulator, the line strainer, and the handgun outlet are easily identified.

A utility sprayer should have a pump that will handle a wide range of chemicals, including abrasive materials. A positive-displacement pump of the piston or plunger type is best; it should be capable of operating at any pressure up to 400 to 500 psi (2,750-3,450 kPa). An unloader-type pressure-control valve is needed to protect the pump. A large-capacity screen that will stand up under high suction pressure is essential because the solid material in a wettable-powder suspension will build up in screen openings. A partly plugged screen can starve the pump.

The tank should be equipped with a mechanical agitator. Wettable-powder spray mixtures must be vigorously agitated to maintain a uniform suspension.

If you use a hydraulic agitator, make certain that the pump has adequate capacity to supply liquid for the boom or handgun, agitator nozzles, and bypass liquid (see "Agitation").

A HANDGUN (Figure 17) is useful for spraying barns and cattle and for spot applications around the farmstead or in the field. Buy a good-quality handgun and an adequate length of high-pressure, chemical-resistant hose. A fast-acting shutoff handle helps save expensive chemicals. The gun should be sturdy to withstand hard wear and high pressure.

The single-nozzle gun is useful for spraying cattle held in crowding pens. It can be equipped with a wide selection of orifice discs or tips. Select the right size of tip for the spraying to be done. Too large a tip wastes expensive spray material; too small a one makes the job take too long. One type of single-nozzle gun is adjustable for any pattern from

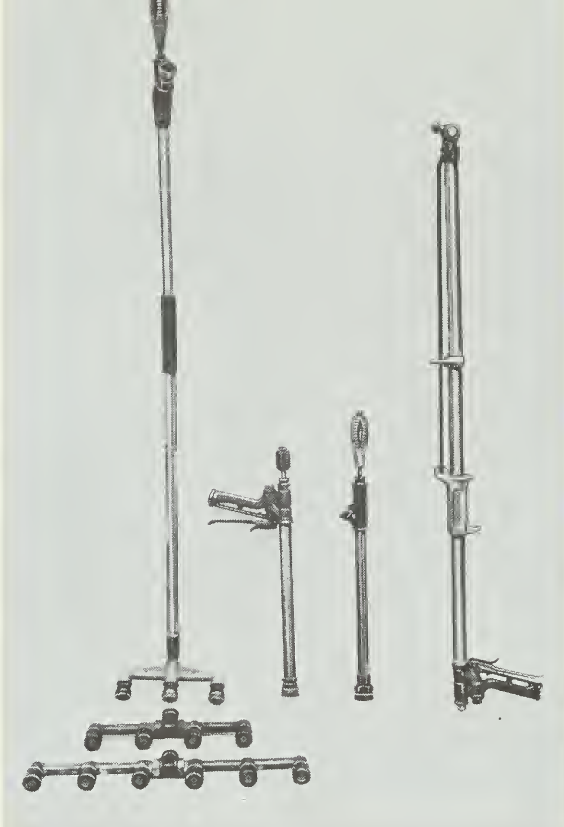


FIGURE 17. Handguns. *Left,* multinozzle spray gun; *center,* single-nozzle utility guns shown with and without a trigger handle; *right* single-nozzle gun with trigger handle. The nozzle body is a swivel type and the slide handle and control rod direct the spray when treating cattle. Interchangeable discs or tips are available for all guns shown.

a solid stream to a fine cone spray. Sometimes called a utility or pencil gun, it is useful for washdown work, handling water-base paint, and general spraying.

The multinozzle gun is useful for spraying barns to control flies, farmsteads to control mosquitoes, and brush along roadsides, ditch banks, and other out-of-the-way places.

The handgun nozzle should have an abrasion-resistant tip. Stainless steel resists abrasion better than brass or aluminum. Stainless-steel discs with tungsten-carbide inserts are more expensive than other types, but are economical where large quantities of abrasive materials are to be sprayed at high pressures.

FIGURE 18. A trailer-mounted sprayer. Tandem wheels are used to support a large-capacity tank; outrigger wheels provide boom support. The pump is PTO-mounted and the spray shutoff valve is controlled by a rope (see Figure 9).

FIGURE 19. A swather-mounted sprayer.

SPRAYER MOUNTS

The TRAILER-MOUNTED SPRAYER is generally used to apply herbicides or insecticides to field and row crops. This sprayer is usually equipped with a tank of 100-200 gallons (455-910 litres) capacity; larger tanks should be carried on oversized tires or on tandem wheels (Figure 18). Generally, the liquid sloshes less in a tank mounted crosswise than in one mounted lengthwise. A trailer-mounted sprayer should be stable and have a sturdy frame. For row crops, the sprayer needs an axle clearance of 30 inches (75 cm) or more and wheel-tread adjustment for various row spacings.

The TRACTOR-MOUNTED SPRAYER costs less than the trailer type and is readily adapted for use in row crops. It is excellent for use on small acreages, for spraying row crops, or as a second unit where one machine is used for insecticides and fungicides and the other for herbicides. The capacity of a rear-mounted tank or of two straddle-mounted tanks should not exceed 100 gallons (455 litres). Excessive weight on the tractor may damage the crop. The boom needs adequate bracing because it is generally suspended from the tractor. It should not be more than 30 feet (9 m) long or it will sway and whip on rough fields and distribute the spray unevenly.

The SWATHER-MOUNTED FIELD SPRAYER (Figure 19) is often preferred, because you can use the swather during the off-season. The self-propelled swather frame makes an excellent base for the sprayer, which may be

equipped with either a 100-gallon (455-litre) or a larger tank. Consult the swather-equipment manufacturer before using a larger tank or you may overload the swather framework and wheels. Check your speed of travel carefully and maintain constant speed for best results.

The FLAT-BED UTILITY SPRAYER is usually carried in a truck, which provides capacity for large loads and easy movement over long distances. A truck-mounted sprayer is not generally used for field spraying because of the low and uniform speed required for best results.

SPECIAL SPRAYING TECHNIQUES

Hydraulic spraying, with the use of a water carrier and a pesticide that dissolves in water or an emulsifiable concentrate that forms an emulsion with water, has been used on Canadian farms for many years. Such solutions or emulsions have the same viscosity as water, and in a spray the droplets drift and settle like water droplets. Special spraying techniques have been developed in an attempt to reduce the spray drift hazard.

INVERT EMULSIONS form in the sprayer tank when a small amount of water is mixed into a solution of pesticide, emulsifier, and oil (often diesel fuel). A spray with a consistency like cream is delivered by the nozzles.

BIVERT EMULSIONS are multiphase invert emulsions that have been developed recently. Special emulsifiers must be purchased for each pesticide. The emulsifier is added to a tank containing diesel oil (ratio 1:14). The pesticide is added to the water tank. The water phase is mixed with the oil phase (ratio 6:1) in a mixing chamber on the suction side of a positive-displacement-type pump (see "Bivert Sprayers"). The pump forces the mixture to special nozzles that deliver a thick mayonnaiselike spray. This spray is claimed to eliminate drift. The manufacturer's directions must be followed exactly.

A THICKENING AGENT added to the spray mix in the tank produces a gellike mass that must be pumped by a positive-displacement pump.

A PARTICULATING AGENT injected into the spray in the tank produces large particles (containing the pesticide) at the nozzle. No special equipment, other than the injector, is required to apply a particulated spray. Considerable care and skill are required because the acidity and temperature of the water, as well as other factors, affect the proper formation of large particles at the nozzle. Drift control with particulated sprays, as with thickened sprays, is reported to be excellent.

DRIBBLE BARS have been developed to apply soluble pesticides where spray application must be precisely controlled. In row-crop spraying the use of a dribble bar and shields provides a means of applying pesticides to the soil between rows while protecting the crop in the rows. Dribble bars operate at low pressure and use large volumes of water.

A special DRIBBLE-TYPE NOZZLE, fitted to a vibrating unit operated by a small direct-current electric motor, has been used to spray where drift control is critical. The nozzle is oscillated at a high frequency to produce a fan-spray pattern. Low pressures of 1 to 6 psi (7-41 kPa) produce a spray free from droplet drift. The nozzle is fitted with an adjustable and replaceable sleeve, which allows for various spray widths up to 3 feet (1 m) from each nozzle. The nozzles, called 'Vibrajet' nozzles, can be used for spraying between crop rows or for full-coverage spraying depending on the sleeve used.

AGITATION

When pesticides in the form of solutions or emulsions are being sprayed, the return flow from the bypass pressure regulator usually is sufficient to mix the contents of the tank. The return flow should not be less than 10 percent of the boom output, or not less than ½ gpm (2.25 litres/min), when the sprayer is operating. The flow should be directed to the bottom of the tank (see Figure 1).

MECHANICAL AGITATION has been used satisfactorily for many years to keep wettable powders in suspension. Where wettable powders are sprayed often, mechanical agitation is preferred, and a tank with mechanical agitation is a good investment.

HYDRAULIC AGITATION will, if properly used, keep wettable powders in suspension. Do not depend on the return flow from the bypass pressure regulator. Connect the agitator line to the pressure side of the pump. Do not connect the agitator line and agitator nozzles to the line from the bypass pressure regulator. Make certain that the pump has sufficient capacity to supply the boom, the agitator line, and some bypass flow. When installing agitator nozzles (see "Nozzles"), follow the manufacturer's recommendations. The nozzles must be rigidly installed near the bottom of the tank. As a rule the agitator line will require 3 to 6 gpm for each 100 gallons of tank capacity (3-6 litres/min per 100 litres) (see "Control of Sprayer Output"). Use the gate valve in the agitator line (see Figure 1) to restrict flow sufficiently to prevent foaming in the tank.

SPRAY DRIFT

Herbicide, fungicide, and insecticide sprays may drift for considerable distances in two ways: as very fine droplets carried by wind; and as vapor from a volatile chemical that, when diffused in fairly calm air, may damage susceptible plants.

The drift of pesticide sprays is a serious problem. In one study, drift deposits from droplet drift were measured on the downwind side of a field sprayed in a 10-mph (16-km/h) wind with 8 ounces per acre (560 g/ha) of 2,4-D. The deposits were 0.29 ounce per acre at 250 feet (20.3 g/ha at 76 m) and 0.15 ounce per acre at 1,200 feet (10.5 g/ha at 366 m). Measurable deposits were detected 1 mile (1.6 km) downwind.

The size of the droplets in a spray varies from very fine (fog-size and mist-size droplets, less than 100 microns in diameter) to fairly large (light and moderate rain-size droplets, 500 to 1,000 microns in diameter). Fog-size and mist-size droplets drift readily. At low pressure (e.g., 20 psi or 138 kPa), low-volume spray nozzles produce very few fine droplets (about 15 percent by volume). The proportion of fine droplets in the spray increases rapidly as pressure is increased to 30 psi (205 kPa) and higher. At 40 psi (275 kPa) the spray contains an appreciable quantity of fine droplets (about 50 percent by volume). At 60 psi (415 kPa) the spray consists mostly of fine droplets (about 75 percent by volume). At pressures of 40 psi (275 kPa) and higher, the drift hazard is great.

Field research with herbicides such as 2,4-D has repeatedly demonstrated that, when the recommended amount of chemical is applied in 10 gpa (110 litres/ha) of water, weed control is as good as that obtained when 3 to 5 gpa (34-56 litres/ha) are used, and crop tolerance is greater.

Do not allow herbicides to drift onto crops, ornamental flowers, shrubs, or trees that are susceptible to the chemical. Do not expose yourself continually to chemical vapors and drift; operate in a cross breeze if possible. Do not let insecticides drift across garden areas or fields containing forage. Remember, pesticides can be poisonous to man and animals and must always be used with great care.

To reduce the possibility of spray drift:

Apply pesticides in at least 10 gpa of solution at a pressure of 30 psi (110 litres/ha at 205 kPa), or lower if the spray pattern is maintained. The control of drift is more important than the inconvenience of using more water.

Use special spraying techniques where they are applicable (see "Special Spraying Techniques").

Do not spray when winds exceed 8 to 10 mph (13-16 km/h).

Replace faulty nozzles and clean partly plugged nozzles, which may cause fogging.

If obtainable, use a chemical that will reduce the vapor drift.

SPRAYER OPERATION

CONTROL OF SPRAYER OUTPUT

Sprayer output is normally governed by four factors: nozzle capacity, speed of travel, fluid pressure, and nozzle spacing (width covered by each nozzle).

1. Nozzle capacity is the volume of liquid delivered by the nozzle in gallons per minute (or litres/min). Capacity is determined by:

The orifice size of the nozzle

The pressure of the spray solution at the nozzle.

Nozzles are generally rated in gpm (litres/min) at a specific pressure. They are sometimes rated in gpa (litres/ha) for field sprayer use, but such a rating is misleading because it is true only if the nozzle is used at the specified pressure, spacing, and speed.

Fluid pressure affects nozzle output, spray pattern, and droplet size. Very low pressures produce poor spray patterns, and high pressures (40 psi or 275 kPa and higher) produce fine, foglike sprays that will drift. Liquid pressure should be kept as low as possible but within the recommended range for the work to be done. Do not adjust the pressure to change the nozzle output.

2. Orifice size is an important factor. The nozzle orifice is subject to wear. As the size of the hole increases the amount of spray material delivered increases and the spray pattern changes. In a recent survey of 1,171 farm sprayers being used in Western Canada, 40 percent of the brass nozzles tested were found to have an increased output of greater than 10 percent of their original rating.

Any nozzle that delivers 10 percent more than it did when it was new should be replaced because the pesticide

FIGURE 20 A low-speed farm speedometer.

will not be distributed uniformly on the crop. This lack of uniformity may result in crop damage and in variations in pest control.

3. Speed of travel must be carefully regulated. Any variation in forward speed changes the number of gallons of spray material applied to an area. Halving the forward speed doubles the application volume. Because tractor wheels slip and truck speedometers cannot be read accurately at speeds below 10 mph, speed should be calibrated (see "Calibration"). A low-speed farm speedometer (Figure 20) is available at many automotive supply stores. This type of speedometer is easily attached to a sprayer, is inexpensive, and is useful for maintaining a constant forward speed.

4. Nozzle spacing is usually fixed on field-boom sprayers but is adjustable on most row-crop sprayers.

To adjust the spray output of a field sprayer, change the nozzle size, or the speed of travel, or both.

The relationship between the various factors that determine sprayer output is shown in the following formulas:

For full-coverage field spraying, gallons per acre =

$$\frac{5{,}940 \times \text{gallons per minute (one nozzle)}}{\text{miles per hour} \times \text{nozzle spacing (inches)}}$$

or, litres/ha =

$$\frac{60{,}000 \times \text{litres/min (one nozzle)}}{\text{km/h} \times \text{nozzle spacing (cm)}}$$

For row-crop spraying, gallons per acre =

$$\frac{5{,}940 \times \text{gpm (one nozzle)} \times \text{no. of nozzles per row}}{\text{miles per hour} \times \text{row spacing (inches)}}$$

or, litres/ha =

$$\frac{60{,}000 \times \text{litres/min (one nozzle)} \times \text{no. of nozzles per row}}{\text{km/h} \times \text{row spacing (cm)}}$$

For band spraying, gallons per acre (in the band) =

$$\frac{5{,}940 \times \text{gallons per minute (one nozzle)}}{\text{miles per hour} \times \text{band width (inches)}}$$

or, litres/ha (in the band) =

$$\frac{60{,}000 \times \text{litres/min (one nozzle)}}{\text{km/h} \times \text{band width (cm)}}$$

For a change in speed only,

$$\frac{\text{miles per hour}_2}{\text{miles per hour}_1} = \frac{\text{gallons per acre}_1}{\text{gallons per acre}_2}$$

$$\text{or} \quad \frac{\text{km/h}_2}{\text{km/h}_1} = \frac{\text{litres/ha}_1}{\text{litres/ha}_2}$$

The correct size of nozzle tip needed for a major change in the output of a sprayer can be determined by either of two methods. The first method is to obtain the information from nozzle performance tables available for inspection at most implement agencies. Note: These tables usually list nozzle-tip output in U.S. gallons. To obtain the output in Imperial gallons multiply the output in U.S. gallons by 5/6 (or to obtain the output in litres multiply the output in U.S. gallons by 3.785). The second method is to calculate the required nozzle output by using the appropriate formula mentioned previously. Two examples follow.

1. A field sprayer is used to apply 2,4-D at 10 gpa at a speed of 4 mph and a pressure of 30 psi (112 litres/ha at 6.4 km/h and 205 kPa). The nozzles are 20 inches (50 cm) apart. Use the formula for full-coverage field spraying, which can be rewritten as follows:

Gallons per minute per nozzle =

$$\frac{\text{gallons per acre} \times \text{miles per hour} \times \text{nozzle spacing (inches)}}{5{,}940} =$$

$$\frac{10 \times 4 \times 20}{5{,}940} = 0.135$$

or, litres/min per nozzle =

$$\frac{\text{litres/ha} \times \text{km/h} \times \text{nozzle spacing (cm)}}{60{,}000} =$$

$$\frac{112 \times 6.4 \times 50}{60{,}000} = 0.597 \text{ litres/min, or } 597 \text{ ml/min}$$

2. A row-crop sprayer is used to apply 150 gpa of spray at a speed of 3 mph and a pressure of 40 psi (1,685 litres/ha at 4.8 km/h and 275 kPa), with five nozzles for each 40-inch-spaced (102-cm) row. Use the formula for row-crop spraying, which can be rewritten as follows:

Gallons per minute per nozzle =

$$\frac{\text{gallons per acre} \times \text{miles per hour} \times \text{row spacing (inches)}}{\text{no. of nozzles per row} \times 5{,}940} =$$

$$\frac{150 \times 3 \times 40}{5 \times 5{,}940} = 0.61$$

or, litres/min per nozzle =

$$\frac{\text{litres/ha} \times \text{km/h} \times \text{row spacing (cm)}}{\text{no. of nozzles per row} \times 60{,}000} =$$

$$\frac{1{,}685 \times 4.8 \times 102}{5 \times 60{,}000} = 2.75 \text{ litres/min}$$

Order nozzle tips with an output as close as possible to the calculated value and within the desired pressure range. Install the tips and calibrate the sprayer.

The capacity of the sprayer pump (gpm or litres/min) sometimes limits the spray volume (gpa or litres/ha) that can be applied. The capacity of the pump can be obtained either from the manufacturer's tables or by measurement.

To measure the pump output:

Disconnect the bypass pressure return line from the tank, shut off the boom, and connect a handgun to the pressure side of the pump.

Operate the sprayer at the desired pressure and at the proper pump speed for 1 minute. Catch all the water delivered by the handgun and the bypass pressure return line. When no handgun is available, catch the water delivered by all the nozzles on the boom.

Add the number of gallons (or litres) of water collected in 1 minute from the bypass pressure return line and the handgun or all nozzles on the boom to determine the actual capacity of the pump (gpm or litres/min).

This measurement will indicate whether the pump has sufficient capacity to handle required spray jobs adequately.

If a new pump is needed, procure one that has the highest anticipated volume output. Calculate the required pump output as follows:

(a) Spray output, gallons per minute =

$$\frac{\text{miles per hour} \times \text{swath width (feet)} \times \text{gallons per acre}}{495}$$

$$\text{or, litres/min} = \frac{\text{km/h} \times \text{swath width (m)} \times \text{litres/ha}}{600}$$

(b) Allowance of 25 percent for pump wear and bypass =

$$\frac{25}{100} \times \text{spray output}$$

(c) Agitator line requirement (if wettable powders are to be used) = gallons per minute from one agitator nozzle × number of agitator nozzles (litres/min × no. of nozzles)

Pump capacity required for spraying solutions or emulsions = (a) + (b).

Pump capacity required if hydraulic agitation is used = (a) + (b) + (c).

Before you purchase a new sprayer, consider the use of mechanical agitation for spraying wettable powders.

Mechanical agitators are trouble-free and less expensive than the larger pumps required to supply the agitator line.

CALIBRATION

There are many ways to calibrate a sprayer, that is, to determine the volume applied in gpa (litres/ha). The following method is straightforward, and the calculations are simple:

Operate the sprayer to ensure that it is functioning properly at the desired pressure.

Check the nozzle performance. Fill the tank about half full of water. Catch the output of each nozzle for 1 minute and measure this water in fluid ounces with a measuring cup. Any nozzle tip that delivers more than 10 percent above its rating should be replaced. Replace the whole set of tips when measurement indicates appreciable wear. This will occur after about 100 hours of use with some nozzles, or after a few hours if brass tips are used for spraying wettable-powder suspensions.

Set out two stakes 660 feet (40 rods or 200 m) apart in the field.

Pick a level spot and fill the sprayer tank with water. Operate the sprayer to ensure that the supply lines and boom are full before finally filling the tank. Record the water level on a measuring stick.

Spray between the stakes in both directions at a definite speed and pressure; turn the boom on as you pass the first stake and off as you pass the last stake in each direction. If the sprayer is not equipped with a low-speed speedometer (see Figure 20), record the time required to travel 660 feet (200 m) while spraying between the stakes. Note the tractor gear used and mark the throttle setting.

Carefully measure the amount of water required to refill the tank to the original mark on the measuring stick. This is the amount needed for spraying a distance of 1,320 feet (400 m).

Calculate the application volume in gpa by using the following formula:

$$\text{gallons per acre} = \frac{\text{gallons of water added} \times 33}{\text{boom length (feet)}}$$

To calculate the application volume in litres/ha, use the following formula:

$$\text{litres/ha} = \frac{\text{litres of water added} \times 25}{\text{boom length (m)}}$$

Note: Boom length, as used in this formula, is not the measured length of the spray boom pipe but that of the spray swath. For single-coverage spraying, the boom length is equal to the number of nozzles times the nozzle spacing.

The speed of travel can be determined from the following table:

Time to travel 660 feet (min)	(sec)	Forward speed (mph)	Time to travel 200 m (min)	(sec)	Forward speed (km/h)
7	30	1	12	00	1
3	45	2	6	00	2
2	30	3	3	00	4
1	52	4	2	00	6
1	30	5	1	30	8
1	14	6	1	12	10

If it is not practical or convenient to use calibration stakes 660 feet (200 m) apart and a shorter distance is necessary, use the longest possible distance between stakes to obtain an accurate calibration. Calculate the ground speed by using the following formula:

$$\text{miles per hour} = \frac{0.682 \times \text{distance traveled (feet)}}{\text{time (seconds)}}$$

$$\text{or km/h} = \frac{3.6 \times \text{distance traveled (m)}}{\text{time (seconds)}}$$

Calculate the application volume as follows:

gallons per acre =

$$\frac{\text{gallons of water added} \times 33 \times 1{,}320}{\text{boom length (feet)} \times \text{distance traveled (feet)}}$$

$$\text{or litres/ha} = \frac{\text{litres added} \times 25 \times 400}{\text{boom length (m)} \times \text{distance (m)}}$$

The following are sample calibration calculations for different types of sprayers, when the calibration stakes are 660 feet (200 m) apart.

If a boom-type sprayer has a 40-foot (12.2-m) boom and 12 gallons (54.5 litres) of water are required to refill the tank, the application volume is

$$\frac{12 \times 33}{40} = 9.9 \text{ gpa, or } \frac{54.5 \times 25}{12.2} = 111.7 \text{ litres/ha or } 112 \text{ litres/ha}$$

If a row-crop sprayer covers six rows and the row width is 36 inches (90 cm), then the total width of the spray pattern (boom length) is

$$\frac{6 \times 36}{12} = 18 \text{ feet, or } \frac{6 \times 90}{100} = 5.4 \text{ m}$$

and, if 16 gallons (72.7 litres) of water are required to refill the tank, the application volume is

$$\frac{16 \times 33}{18} = 29.3 \text{ gpa, or } \frac{72.7 \times 25}{5.4} = 336.5 \text{ litres/ha}$$

If a band sprayer has four nozzles and each nozzle covers a 14-inch (35-cm) band, the total width of the spray pattern (boom length) is

$$\frac{4 \times 14}{12} = 4.7 \text{ feet, or } \frac{4 \times 35}{100} = 1.4 \text{ m}$$

and, if 2 gallons (9 litres) of water are required to refill the tank, the application volume is

$$\frac{2 \times 33}{4.7} = 14.0 \text{ gpa, or } \frac{9 \times 25}{1.4} = 160 \text{ litres/ha}$$

Note: In band spraying, the area actually sprayed is not the same as the field area. Recommendations in publications on pest control are based on acres (hectares) actually sprayed. The field area covered by each tankful of spray material can be calculated as follows:

$$\frac{\text{no. of gallons in tank} \times \text{row width (inches)}}{\text{application volume (gpa)} \times \text{band spray width (inches)}}$$

$$\text{or } \frac{\text{no. of litres in tank} \times \text{row width (cm)}}{\text{application volume (litres/ha)} \times \text{band spray width (cm)}}$$

If the band sprayer previously mentioned had 82 gallons (373 litres) of spray mix in the tank and was used on 36-inch (90-cm) rows, the field area that could be sprayed with the 82 gallons (373 litres) would be:

$$\frac{82 \times 36}{14 \times 14} = 15 \text{ acres, or } \frac{373 \times 90}{160 \times 35} = 6 \text{ ha}$$

If the calibration discloses that the sprayer output requires adjustment, change the speed of travel.

If a row-crop sprayer traveling at 5 mph (8 km/h) applies 29.3 gpa (330 litres/ha) and a more desirable application volume is 40 gpa (450 litres/ha), calculate a new speed by using the following formula:

$$\text{Required speed (mph)} = \frac{\text{present speed (mph)} \times \text{present output (gpa)}}{\text{desired output (gpa)}}$$

$$\text{or km/h} = \frac{\text{present speed (km/h)} \times \text{present output (litres/ha)}}{\text{desired output (litres/ha)}}$$

The new speed will be:

$$\frac{5 \times 29.3}{40} = 3.66 \text{ mph, or } \frac{8 \times 330}{450} = 5.86 \text{ km/h}$$

Pull the sprayer past the calibration stakes to check the speed setting and the sprayer output. Maintain the same pressure and the same forward speed in the field as were used during the final calibration run.

If adjustments in speed fail to provide the desired spray volume, then you need different nozzle tips (see "Control of Sprayer Output").

CALCULATION OF SPRAY MIXTURES

Agricultural extension workers usually express the quantity of chemical needed to control a weed, insect, or disease as the amount of the active ingredient or acid equivalent; but directions on the can or package may be given in amounts of the product. The label on the can or package also indicates the amount of actual chemical in a gallon or pound of the product. Two simple formulas allow the conversion of active ingredient (or acid equivalent) recommendations to ounces or pounds of commercial product. If the active ingredient content of a liquid product is given on the label in ounces or pounds, use this formula:

$$\text{Ounces (fluid) of commercial product per acre} = \frac{\text{ounces active ingredient recommended per acre}}{\text{ounces active ingredient per gallon}} \times 160$$

or in metric units:

$$\text{Litres of commercial product per hectare} = \frac{\text{active ingredient recommended (g/ha)}}{\text{active ingredient in product (g/litre)}}$$

If the active ingredient content of a dry powder product is given on the label in percent, use this formula:

$$\text{Pounds of commercial product per acre} = \frac{\text{pounds active ingredient recommended per acre}}{\text{percent active ingredient}} \times 100$$

or: Kilograms of commercial product per hectare =

$$\frac{\text{active ingredient recommended (kg/ha)}}{\text{percent active ingredient}} \times 100$$

Mixing instructions are usually given on the label, but the mixing proportions can be calculated as in the following examples.

A cereal crop is to be sprayed with 6 ounces acid equivalent of 2,4-D per acre (420 g/ha). The commercial product contains 64 ounces (i.e., 4 pounds) acid equivalent per gallon (2 kg in a 5-litre can, or 400 g/litre). The application is to be made at 10 gpa (112 litres/ha) and the sprayer tank holds 200 gallons (1,000 litres). The amount of commercial 2,4-D required is 6/64 × 160 = 15 fluid ounces for each acre (420/400 = 1.05 litres/ha). Each 200-gallon tankful will spray 200/10 = 20 acres (a 1,000-litre tankful will spray 1,000/112 = 8.9 ha). Therefore each tankful requires 20 × 15 = 300 fluid ounces or 300/160 = 1 7/8 Imperial gallons of commercial product (1.05 × 8.9 = 9.345 litres).

An 80 percent wettable powder is to be applied at the rate of 2 pounds active ingredient per acre (2.25 kg/ha) in a band. The row-crop sprayer applies the wettable-powder suspension at the rate of 15 gallons per sprayed acre (170 litres/ha), and the tank holds 90 gallons (400 litres). The bands are 10 inches wide on 24-inch row centers (22 cm wide, 60-cm centers). The amount of commercial product required is 2/80 × 100 = 2.5 pounds per acre (2.25/80 × 100 = 2.81 kg/ha), the number of sprayed acres per 90-gallon tankful is 90/15 = 6 (per 400-litre tankful, 400/170 = 2.35 ha), and each tankful requires 6 × 25 = 15 pounds of product (2.35 × 2.81 = 6.6 kg). The field area that can be treated with the 90 gallons of spray is 90/15 × 24/10 = 14.4 acres (with 400 litres it is 400/170 × 60/25 = 5.65 ha).

CARE OF THE SPRAYER

Before using the sprayer, clean all dirt, sludge, and scale from the tank, pump, hose lines, boom screens, nozzles, and handgun. Plugged nozzles do a poor spraying job. Check the sprayer thoroughly for worn parts. Examine the pump and recondition it if necessary. Follow the manufacturer's instructions on pump lubrication. Check the pressure gauge, and if its accuracy is doubtful replace it. Be sure that all boom supports and braces are in good condition and are adequate to give proper support in the field. Examine all hoses and connections for leaks, especially the suction hose. An air leak in the suction line seriously interferes with the operation of the pump.

Mix chemicals thoroughly with clean water. Dirt plugs nozzles and screens and causes rapid pump wear. Use a strainer on the suction line when you fill the tank from a ditch, stream, or storage reservoir. Make certain that the strainer on the end of the suction line is suspended in the water so that it will not be in contact with sand and debris. The use of a check valve in combination with the suction strainer will prevent siphoning of the chemical mixture out of the tank back into the ditch, stream, or storage reservoir.

Adjust the height of the field boom and align fan nozzles to overlap spray patterns about 2 inches (10 cm) above the crop (Figure 10). On a row-crop sprayer adjust the boom height to cover the tops of the plants with spray from the overhead nozzles. Adjust the height of the drop pipes and the angle of the swivel nozzles to cover the plants with spray from the sides (Figure 13).

Calibrate the sprayer at least once a year and always operate it at the calibrated speed and pressure (see "Calibration"). A variation of 1 mph or of 10 psi (1.5 km/h or of 69 kPa) can seriously change the rate of most applications. Do not travel faster than about 5 mph (8 km/h) because high-speed operation greatly increases boom sway and whip.

Clean the sprayer daily after each use by flushing the tank, pump, and hoses thoroughly with clean water. Clean the filter, screens, and nozzles. Drain the tank and allow it to dry. The tank may be slowly corroded by some chemicals. Regular cleaning is a worthwhile safeguard.

Use a toothbrush or other soft material to clean a nozzle tip. Never use a piece of wire, a nail, or other metal object because these will damage the orifice, distort the spray pattern, and greatly increase the nozzle's output.

At the end of the season, store the sprayer properly. After decontaminating it, drain the tank, hose lines, pump, and boom; then clean and reassemble the filter and screens. Protect a steel tank with an oil or kerosene coating. Follow the manufacturer's recommendations for storing the pump.

DECONTAMINATION

A sprayer used for herbicides should not be used to apply an insecticide or fungicide to a crop that is sensitive to herbicides. Minute traces of a herbicide that remain in the tank and hoses after ordinary cleaning can cause damage. If, in an emergency, the herbicide sprayer must be used for applying insecticides or fungicides, decontamination of the equipment will provide some assurance against crop damage. Furthermore, because some fungicides and insecticides are highly poisonous, decontamination is a wise safety precaution.

If a pesticide in emulsion form has been used, flush out the tank and system with clean water. Fill the tank and system with a mixture of household ammonia and hot water (1 gallon to 100 gallons or 1:100). Recirculate the solution through the pump for several minutes. Leave the solution in the machine overnight. Again recirculate the cleaning solution, completely drain the tank and system, rinse thoroughly with clean water, and dry out the tank and other parts of the sprayer.

Alternative cleaning solutions are:

2 pounds of washing soda per 100 gallons of water (1 kg per 500 litres). Clean the sprayer in the same manner as described for ammonia.

1 percent solution of commercial activated charcoal. Wash the sprayer for about 2 minutes and rinse thoroughly. This method is fast but expensive.

If a water-soluble herbicide or a wettable-powder pesticide has been used in the sprayer, flush out the tank and system with clean water. Scrub the tank thoroughly with a detergent solution and run it through the system. Rinse out this solution and use the ammonia or soda treatment previously mentioned.

Hoses can become so saturated with chemicals that they cannot be decontaminated. Use separate handgun hoses for herbicides and for other chemicals and never use these hoses for conveying drinking water.

Consult provincial publications for advice on the disposal of spray mixtures drained from sprayers, rinse solutions, chemical containers, unused chemicals, and contaminated hoses.

RECORDS

Records of calibrations and spraying operations are very useful for any sprayer operator and are essential for a custom operator.

The record of calibrations will indicate, by comparison, when sprayer nozzles are worn enough to need replacing. The following type of record has proved useful:

RECORD OF CALIBRATIONS

DATE	FORWARD SPEED MPH (km/h)	PRESSURE PSI (kPa)	GAL. TO REFILL TANK (litres)	APPLIC. RATE GPA (litres/ha)	REMARKS

A record of spraying operations is becoming more essential, especially for the sprayer operator covering a large area of his own or customers' land. Such a record is useful if spraying operations later result in some legal action. A type of record that has proved useful follows:

RECORD OF SPRAYING OPERATIONS

DATE AND TIME	SPRAYER			AREA SPRAYED ACRES (ha)	PESTICIDE USED		WEATHER		
	MPH (km/h)	PSI (kPa)	GPA (litres/ha)		PRODUCT	AMOUNT	TEMP F (C)	WIND MPH (km/h)	WIND DIRECTION

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Figure 3. McGraw-Hill Book Co. (Pump Selection and Application, by T. G. Hicks, 1957)
Figures 4 and 7. John Brooks & Co. Ltd.
Figure 5. Niagara Brand Chemicals
Figure 12. National Sprayer and Duster Association

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GLOSSARY

FLUID MEASURE

Imperial Fluid Measure

20 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon = 160 ounces

U.S. Fluid Measure

16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon = 128 ounces

Metric Fluid Measure

1 litre = 1,000 millilitres (ml)

Conversion Factors

1 Imperial gallon = 1.2 U.S. gallons = 4.546 litres
1 U.S. gallon = 0.833 Imperial gallon = 3.785 litres

MEASURES OF AREA AND DISTANCE

1 rod = 16½ feet = 5½ yards = 5.029 metres
1 acre = 160 square rods = 4,840 square yards = 43,560 square feet = 0.405 hectare
1 mile = 320 rods = 1,760 yards = 5,280 feet = 1.609 kilometres
1 metre (m) = 100 centimetres (cm) = 1,000 millimetres (mm)
1 kilometre (km) = 1,000 metres
1 hectare (ha) = 10,000 square metres (m^2)

MEASURES OF SPEED

mph—miles per hour; 1 mph = 88 feet per minute = 1.609 km/h
km/h—kilometres per hour; 1 km/h = 16.7 metres per minute
rpm—revolutions per minute
PTO—power takeoff; standard PTO speed is 540 rpm, but some tractors are equipped with 1,000-rpm PTO shafts.

SPRAYER TERMS

gpa—gallons per acre
gpm—gallons per minute
litres/ha—litres per hectare
litres/min—litres per minute
psi—pounds per square inch pressure (often called pounds pressure); 1 psi = 6.89 kPa
kPa—kilopascal (1,000 pascals); 1 Pa = 1 N/m^2

CONVERSION FACTORS FOR METRIC SYSTEM

Imperial units	Approximate conversion factor	Results in:	
LINEAR			
inch	x 25	**millimetre**	**(mm)**
foot	x 30	**centimetre**	**(cm)**
yard	x 0.9	**metre**	**(m)**
mile	x 1.6	**kilometre**	**(km)**
AREA			
square inch	x 6.5	**square centimetre**	**(cm^2)**
square foot	x 0.09	**square metre**	**(m^2)**
acre	x 0.40	**hectare**	**(ha)**
VOLUME			
cubic inch	x 16	**cubic centimetre**	**(cm^3)**
cubic foot	x 28	**cubic decimetre**	**(dm^3)**
cubic yard	x 0.8	**cubic metre**	**(m^3)**
fluid ounce	x 28	**millilitre**	**(mℓ)**
pint	x 0.57	**litre**	**(ℓ)**
quart	x 1.1	**litre**	**(ℓ)**
gallon	x 4.5	**litre**	**(ℓ)**
bushel	x 0.36	**hectolitre**	**(hℓ)**
WEIGHT			
ounce	x 28	**gram**	**(g)**
pound	x 0.45	**kilogram**	**(kg)**
short ton (2000 lb)	x 0.9	**tonne**	**(t)**
TEMPERATURE			
degree fahrenheit	°F-32 x 0.56 (or °F-32 x 5/9)	**degree Celsius**	**(°C)**
PRESSURE			
pounds per square inch	x 6.9	**kilopascal**	**(kPa)**
POWER			
horsepower	x 746	**watt**	**(W)**
	x 0.75	**kilowatt**	**(kW)**
SPEED			
feet per second	x 0.30	**metres per second**	**(m/s)**
miles per hour	x 1.6	**kilometres per hour**	**(km/h)**
AGRICULTURE			
bushels per acre	x 0.90	**hectolitres per hectare**	**(hℓ/ha)**
gallons per acre	x 11.23	**litres per hectare**	**(ℓ/ha)**
quarts per acre	x 2.8	**litres per hectare**	**(ℓ/ha)**
pints per acre	x 1.4	**litres per hectare**	**(ℓ/ha)**
fluid ounces per acre	x 70	**millilitres per hectare**	**(mℓ/ha)**
tons per acre	x 2.24	**tonnes per hectare**	**(t/ha)**
pounds per acre	x 1.12	**kilograms per hectare**	**(kg/ha)**
ounces per acre	x 70	**grams per hectare**	**(g/ha)**
plants per acre	x 2.47	**plants per hectare**	**(plants/ha)**

Examples: 2 miles x 1.6 = 32 km; 15 bu/ac x 0.90 = 13.5 hℓ/ha