

Plumbing Systems of Agricultural Sprayers

Robert Grisso, Extension Engineer, Biological Systems Engineering Department, Virginia Tech

The plumbing systems of agricultural sprayers are usually considered foolproof. Sprayer problems may occur if plumbing and/or modifications are improperly done or maintenance is ignored. Retrofitting, addition of electrical control systems, and replacement of pumps or nozzles require proper knowledge of the plumbing system and the implications of these changes to sprayer performance. Routine maintenance of the plumbing system is essential.

Pumps

A major component of the plumbing system is the pump. The characteristics of a particular pump will usually define the plumbing system. Most pumps are categorized as positive displacement or nonpositive displacement pumps.

The positive displacement pump moves a specific volume of liquid with each stroke or revolution. The pump output is proportional to speed and virtually independent of pressure. Examples of positive displacement pumps include piston, roller and diaphragm.

The output of nonpositive pumps varies directly with pump speed and is sensitive to pressure (Figure 1). Typically, the output will decrease dramatically with increasing pressure. An example of a nonpositive pump is a centrifugal pump which has an impeller with curved vanes that rotates at high speeds. The liquid is drawn into the center of the impellers. Then the liquid is dispersed by centrifugal force around the edge of the pump casing and through the outlet.

Characteristics of several pump types are outlined in Table 1. Of these types, roller, centrifugal, and piston pumps are the most widely used on agricultural spraying equipment.

An important factor in pump selection is discharge capacity. The pump should have sufficient capacity to supply all the nozzles and other accessories, provide agitation and offset pump wear (20% greater capacity).

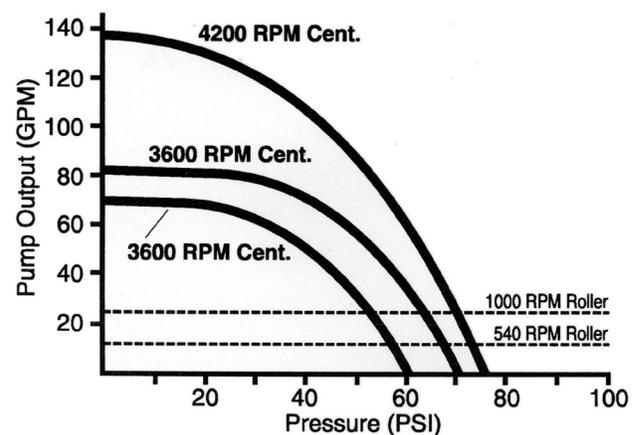


Figure 1. Centrifugal and roller pump performance.

Table 1. Pumps for agricultural sprayers.

Pump Type	Pressure Ranges (psi)	Operating Speeds (rpm)	Flow Rates (gpm)	Displacement Type
Centrifugal	5-80	2000-4500	0-120	nonpositive
Diaphragm	50-850	200-1200	1-60	semipositive
Piston	400-1000	600-1800	5-60	positive
Roller	50-300	300-1000	1-45	positive
Turbine	5-60	600-1200	10-80	nonpositive

Use the following to determine pump capacity:

$$\text{Pump Capacity (gpm)} = \left\{ \begin{array}{l} \text{Boom Requirements (gpm) +} \\ \text{Agitation Requirements (gpm) +} \\ \text{Self Cleaning Strainers (gpm) +} \\ \text{Other Accessories (gpm) +} \\ \text{1 (gpm)} \end{array} \right\} \times 1.2$$

Where:

Boom Requirements (gpm) = Number of nozzles x flow discharge per nozzle (gpm).

Agitation Requirements (gpm) = Use guidelines given in section "Agitation,"

Self Cleaning Strainer (gpm) = Extra flow needed to clean strainer, see section on "Strainers,"

1 (gpm) = Extra flow to assure proper operation of the by-pass valve, and

1.2 = 20% extra capacity for pump wear.

If the output from a pump fails to meet the sprayer nozzle and agitation requirements, the pump should be overhauled or replaced.

Plumbing System for Nonpositive Displacement Pumps

The centrifugal pump is widely used to apply pesticides. One reason for its popularity is the simplicity of the flow control system. The pump is recommended for solutions that require additional mixing (ie. wettable powders) and agitation. Since this is a nonpositive displacement pump, the output can be completely shut off without needing a pressure relief valve. The discharge of the system is controlled by a throttling valve or electrical regulating valve. If used for agitation, the spray solution for jet agitation is routed before the flow control valves.

If a combination of manual and electrical control valves are used, proper sequencing of valves is important. Incorrect valve placement can lead to pressure surges and premature failure of the electric regulator or pressure gauges. Proper arrangement as shown in Figure 2 will allow the manual throttling valve to regulate major pressure changes while the electric regulating valve can be used to "fine tune" nozzle pressure from the operator's platform.

Following are operational guidelines for using a spraying system with a centrifugal pump:

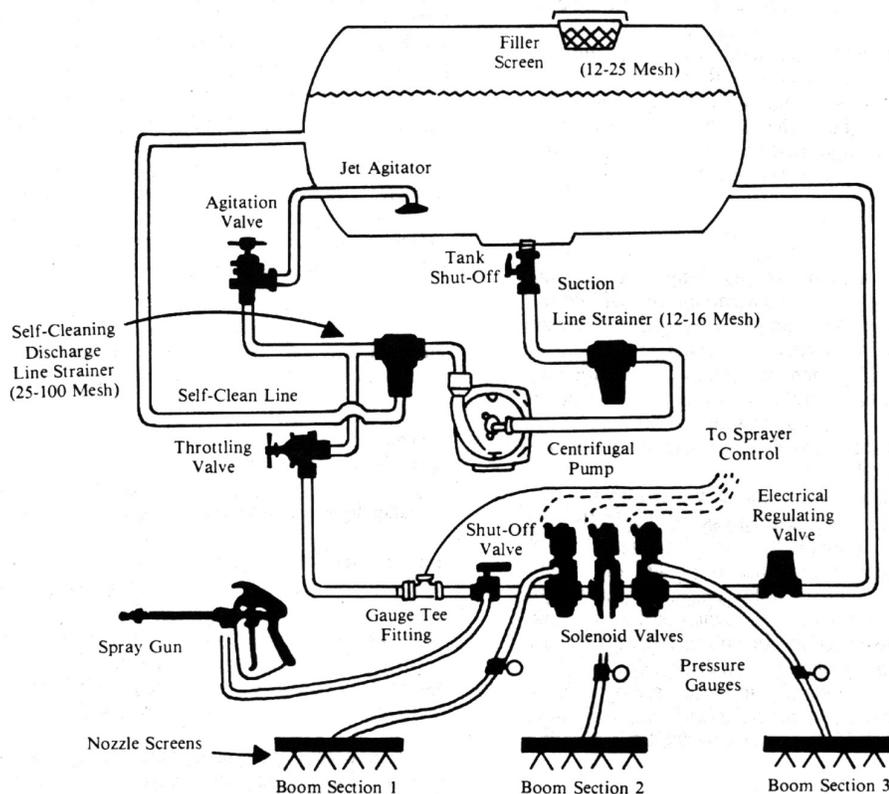


Figure 2. Plumbing diagram for a centrifugal pump (nonpositive displacement pump).

1. Prime pump with all valves fully open.
2. Close the throttling valve while opening the boom solenoid valves.
3. With the pump running, adjust the throttling valve until the pressure gauge indicates the desired pressure.
4. Check for uniform discharge from the nozzles.

Plumbing System for Positive Displacement Pumps

The characteristics of a positive displacement pump require a mechanism to release pressure and prevent damage when all outlets are closed. A spring actuated pressure relief valve insures a safety route to a by-pass line (Figure 3). Use the pressure relief valve (or regulator) to make large pressure adjustments. The pressure relief valve adjusts the flow between the nozzles and the by-pass line back to the tank. An electric regulating valve can be used to “fine tune” the required nozzle pressure.

When positive displacement pumps are used, pressure relief valves designed to handle the system’s maximum pressure are needed. As with nonpositive displacement pumps, the sequencing of the valves is very important to avoid performance problems.

Following are operational guidelines for using a spraying system with a roller pump:

1. Fully open the agitation valve, pressure relief valve, and boom electric ball valves (or spray gun).
2. Start the sprayer. Make sure the nozzles have uniform discharge rates. Adjust the pressure relief valve until the pressure shows about 10 to 15 psi above the desired spraying pressure.
3. Use the electrical regulating valve to “fine tune” the pressure.
4. Shut off the boom valves. If the pressure increases over 10 psi, the pressure relief valve should be replaced with a larger capacity valve or the by-pass line may be too small for the excess flow.
5. Check for uniform discharge from the nozzle.

Hose and Lines

All hoses and fittings should be constructed with quality materials and sufficient strength to handle liquids under maximum pressure. These hoses and lines should be selected based on composition, construction, and size.

Hoses should be flexible, durable, and resistant to sunlight, oil, chemicals, and general abuse such as twisting

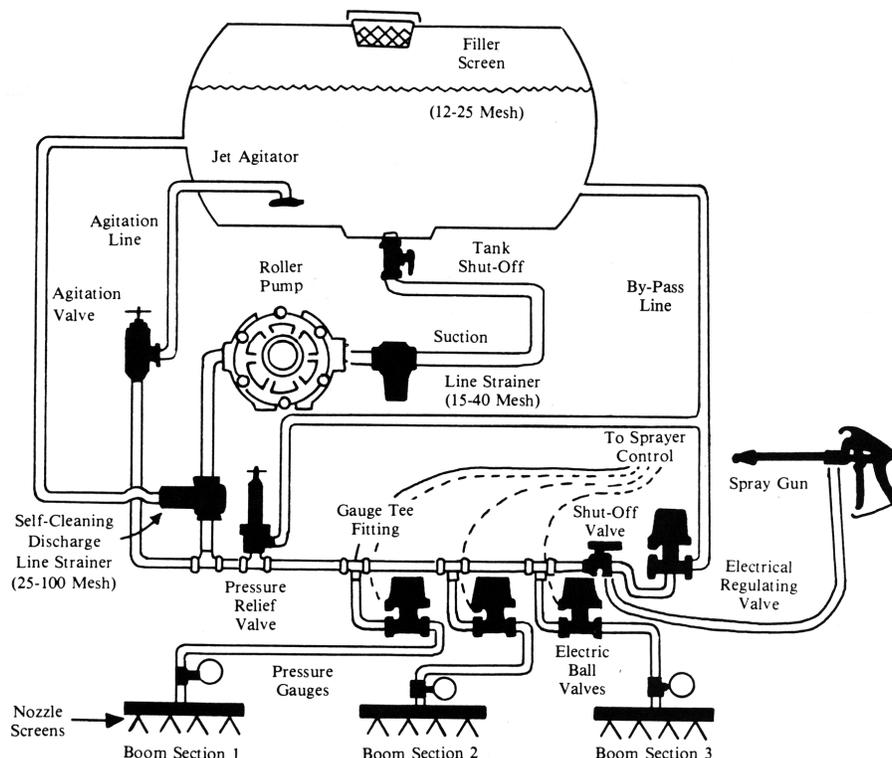


Figure 3. Plumbing diagram for a roller pump (positive displacement pump).

and vibration. The outer coatings of the hose should be resistant to chemicals because they may come in contact with the spray solutions. Sunlight-resistant materials increases durability. Two materials that are chemically resistant are ethylene vinyl acetate (EVA) and ethylene propylene diene monomer (EPDM). A special reinforced hose must be used for suction lines to prevent collapsing.

The suction hoses should be airtight, noncollapsible, as short as possible, and as large as the intake port. A collapsed suction hose can restrict flow and “starve” a pump, causing decreased flow and damage to the pump and seals. When spray pressure cannot be maintained, check the suction line for restrictions.

Lines between the pressure gauge and nozzles should be as direct as possible with minimum fittings, throttle valves, and restrictions. These lines should be plumbed to the center of each spray boom (Figure 3). Spray lines and hoses must be of the proper size. The proper size of these lines will depend on the inside diameter of the hose and the flow capacity (gpm) of the line. Sufficient flow velocity is required so that suspended particles will not settle in the lines. If lines are too small, excessive pressure drop will occur and the flow at the nozzle will be insufficient. A flow velocity below 5 feet per second is recommended. Table 2 gives suggested hose sizes for various flow rates.

Table 2. Recommended hose sizes for various flow rates.

Highest Flow Capacity (gpm)	Hose Size Inside Diameter (inch)	
	Suction Hose	Discharge Hose
0- 1	1/2	1/4
1- 3	1/2	3/8
3- 6	3/4	1/2
6-12	3/4	5/8
12-25	1	3/4
25-50	1-1/4	1
50-100	1-1/2	1-1/4

Many sprayers are constructed with “wet” booms and are fitted with nozzle assemblies that protrude 1/3 to 1/2 of the diameter of the boom. These nozzle assemblies take the spray solution out of the middle of the boom. The wet boom makes it possible to flush out materi-

als like sand and rust in the bottom of the spray boom. Equip a wet boom with plugs or hose-end caps on the boom ends so they can be easily flushed. PVC schedule 90 can be used for a wet boom if supported adequately. Some pesticides will damage PVC so review the compatibility tables. Stainless steel is the best material and can be fixed with hose-end caps to make flushing and draining convenient.

Agitation

The amount of flow required for sufficient agitation depends on the chemical formulation. For example, wetttable powders require more agitation than emulsifiable concentrates to keep them in suspension. Applications that require vigorous agitation may need mechanical agitation such as propellers or paddles on a rotating shaft. For most spraying situations, hydraulic agitation is sufficient.

Hydraulic agitation requires a portion of the flow from the pump to be diverted back to the tank. The amount of flow for agitation will depend on chemical formulation and tank size and shape. As a rule of thumb, use 5 to 10 percent of the tank’s capacity for agitation flow. For example, a 300 gallon tank should have between 15 and 30 gpm of flow into the tank. After selection of the agitation flow rate, select the correct orifice size required (Table 3).

Table 3. Tank agitation capacity.

Orifice Size (in)	Inlet Flow* (gpm)	Outlet Flow* (gpm)
1/8	2.9	9.5
5/32	4.1	13.2
3/16	5.3	15.4
1/4	6.5	19.5
JET-Spring-Loaded	0-15	2.5 times inlet orifice

*Rates given at 30 psi.

The use of siphon caps on the jet agitators can reduce flow requirements by half. The siphon caps increase the flow by venturi action which increases the mixing potential.

A feature shown in Figures 2 and 3 is a separate line and agitation valve for agitation. Often, sprayers are

plumbed with the agitation coming from the by-pass line. This arrangement does not give the operator control over the amount of flow for agitation. For example, when a large flow is needed by the nozzles, there may be insufficient flow from the by-pass line for adequate agitation. But when the nozzles are shut off, all of the flow is diverted into the by-pass line which causes foaming in the tank.

Strainers

Line and nozzle strainers are a very important component of the sprayer's plumbing system. Properly sized and located strainers will prevent plugged nozzles or partially plugged nozzles and the uniformity problems associated with them. The mesh size of a strainer refers to the openings in a screen per linear inch.

For most positive displacement pumps, a suction line strainer between the tank and pump is required. This strainer should have a 30 to 50 mesh screen. A large suction line strainer (12 to 16 mesh) to keep rocks, labels, booklets, etc., out and to protect the pump should be used with a centrifugal pump. The strainer

mesh must be larger so the inlet of a centrifugal pump is not restricted. If restricted, a centrifugal pump will create a vacuum within itself, thus starving the pump. A smaller strainer of 50 mesh should be located on the pressure side of centrifugal pump to protect nozzles and the agitation system.

A beneficial addition for sprayers is a self-cleaning line strainer (Figure 4). These strainers have a high velocity flow over the screen which provides a continuous washing. The additional flow required for this washing action is 6 to 8 gpm per strainer. Additional plumbing and a throttling valve are required to control the flow of wash water.

Screening should be progressively finer from the tank to the nozzles (Table 4). The largest mesh screens should be in the filler opening and in the suction line. The screens need to be keyed to the nozzle orifice size. Screen area should be large enough to prevent pump starvation or excessive pressure losses. As a rule of thumb, use at least 2 square inches of screen area for each gpm of flow in the suction line. Strainers, between pump and nozzles, should have at least 1 square inch of screen area for each gpm of flow.

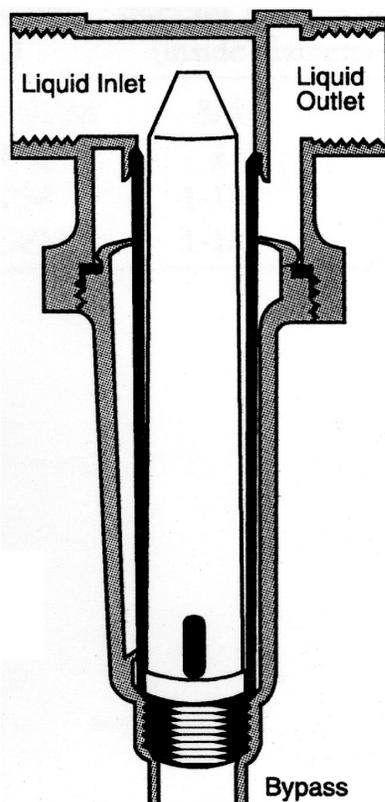


Figure 4. Self-cleaning strainer.

Table 4. Progressive screen mesh in a sprayer.

Where:	Mesh
Filler Opening	12-25
Suction Line (Roller Pump)	15-40
Suction Line (Centrifugal Pump)	12-16
Discharge Line	25-100*
Nozzle	50-100*

* Nozzles requiring greater than 50 mesh size (ie. 80 or 100 mesh) are prone to frequent plugging.

Nozzle screens are very important, since they are the last chance to prevent plugged nozzles. Nozzle screens come in an assortment of sizes and materials. The mesh size of a nozzle screen is dictated by the nozzle orifice size as suggested by the manufacturer's manual. As a general rule, avoid nozzle orifice sizes that require greater than a 50 mesh size (ie. 80 or 100 mesh). Since well water is usually used as a carrier source, the water may contain a small amount of sand and foreign material. A mesh of 80 or greater will easily plug and require frequent cleaning. Also, some pesticide materials may plug small nozzle openings and screens.

Clean strainers frequently. A shut-off valve between the tank and suction line will allow cleaning of the strainers without draining the tank. Always replace damaged or deteriorated strainers.

Maintenance and Care

Many pesticides cause rapid corrosion of metal components in a spraying system. Pesticides should be washed from the whole system immediately after use. Cleaning a sprayer thoroughly not only increases its life but also reduces the chance of cross contamination of chemicals and prevents crop injury. In the case of wettable powders, cleaning prevents settling and caking which may be difficult to remove once the chemical has dried.

Always end the day with an empty tank. When using the same chemical the next day, flushing the sprayer with clean water is sufficient. Always flush the sprayer onto a site listed on the pesticide label. If a different pesticide will be used, a more effective cleaning is necessary. The cleaning solution will depend on the type of pesticide. Always check the pesticide label for specific cleaning instructions.

After cleaning, remove the nozzles and flush the system twice with clean water. Clean nozzles and screens in a strong detergent solution or kerosene, using a soft brush. Use chemical-resistance gloves for your protection.

The sprayer should be protected from deterioration during the storage period. Use automotive antifreeze with a rust inhibitor. This not only protects against corrosion but will reduce freezing in case all the water was not drained. Seal off any openings to prevent entry of dirt, debris or insects. Store the sprayer in a place secure from damage from other equipment or livestock. Make a list of all parts in need of replacement and order them well in advance of the next spray season.

Acknowledgments

The authors acknowledge the contributions made by Mike Weaver, Kevin Bradley, Scott Hagood, and Henry Wilson in previous versions of the factsheet.

Resources

Strategies to Reduce Spray Drift, Kansas State University Agricultural Experiment Station and Cooperative Extension Service publication MF-2444; <https://bookstore.ksre.ksu.edu/pubs/MF2444.pdf> (accessed: February 2020)

Fine Tuning a Sprayer with "Ounce" Calibration Method, Virginia Cooperative Extension publication 442-453 (BSE-178P); <http://pubs.ext.vt.edu/442/442-453/442-453.html> (accessed: February 2020)

Nozzles Selection and Sizing, Virginia Cooperative Extension, publication 442-032 (BSE-262P); <https://www.pubs.ext.vt.edu/442/442-032/442-032.html> (accessed: February 2020)

Droplet Chart / Selection Guide, Virginia Cooperative Extension, publication 442-031 (BSE-263P); <https://www.pubs.ext.vt.edu/442/442-031/442-031.html> (accessed: February 2020)

Weight and Measures Conversions

Weight

16 ounces = 1 pound = 453.6 grams
1 gallon water = 8.34 pounds = 3.78 liters

Liquid Measure

1 fluid ounce = 2 tablespoons = 29.57 milliliters
16 fluid ounces = 1 pint = 2 cups
8 pints = 4 quarts = 1 gallon

Length

3 feet = 1 yard = 91.44 centimeters
16.5 feet = 1 rod
5280 feet = 1 mile = 1.61 kilometers
320 rods = 1 mile

Area

9 square feet = 1 square yard
43560 square feet = 1 acre = 160 square rods
1 acre = .405 hectare
640 acres = 1 square mile

Speed

88 feet per minute = 1 mph

1 mph = 1.61 km/h

Volume

27 cubic feet = 1 cubic yard

1 cubic foot = 1728 cubic inches = 7.48 gallons

1 gallon = 231 cubic inches

1 cubic foot = 0.028 cubic meters

Common Abbreviations and Terms Used:

gpm = gallons per minute

gpa = gallons per acre

psi = pounds per square inch

mph = miles per hour

rpm = revolutions per minute

gph = gallons per hour

fpm = feet per minute