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**ANR-1243**

ALABAMA A&M AND AUBURN UNIVERSITIES

# **Greenhouse Fertilizer Injectors: Selection, Maintenance, and Calibration**



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# Greenhouse Fertilizer Injectors: Selection, Maintenance, and Calibration

## Table of Contents

How Injectors Work	Page 4
Venturi Injectors	Page 4
Positive Displacement Injectors	Page 6
Choosing an Injector	Page 10
Installing an Injector	Page 13
Water Hammer	Page 14
Using an Injector	Page 14
Acid Injection	Page 15
Stock Tanks	Page 15
Maintaining an Injector	Page 16
Checking Water Flow Rate	Page 16
Calibrating an Injector	Page 17
Fertilizer Calculations	Page 19
Bibliography	Page 22
Appendix	Page 22

*Fertilizer injectors are mechanical devices used to apply water-soluble fertilizers, pesticides, plant growth regulators, wetting agents, disinfectants, and mineral acids during crop production. They are a vital part of modern greenhouse operations. Since the introduction of injectors or proportioners, growers have enjoyed an easy, time- and labor-saving method of applying liquid chemical solutions to their crops. Despite the advantages, many growers have had at least one experience with a compromised, damaged, or even ruined crop with the cause being traced to a malfunctioning injector. Just like other mechanical devices, proper and timely maintenance and, calibration are crucial to ensure optimum injector performance and, thus, healthy crops.*

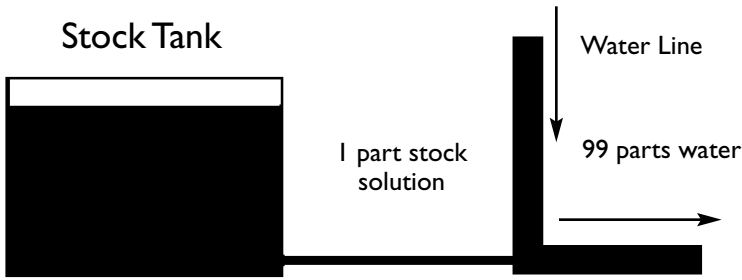
## **How Injectors Work**

Injectors take a small amount of concentrated chemical solution, such as water soluble fertilizer dissolved in water in a stock tank, and introduce it into the waterline for delivery to plants. One part of stock solution is mixed with “x” parts of water in the waterline, where “x” is determined by the injector ratio. Example, for a ratio of 1:100, 1 part of stock solution combines with 99 parts of water for a total of 100 parts of final solution. The size of the stock tank can vary from as small as 5 gallons to as large as 2,000 gallons. A 5-gallon stock tank used with a 1:100 injector ratio will yield 500 gallons of final solution. Often, injector ratios are expressed as a percentage. Example, a 1:100 ratio equals a 1 percent solution (Figure 1). Injectors work on one of two principles as seen in the Venturi-type injectors and the positive displacement injectors.

### **Venturi Injectors**

Venturi-type injectors, such as Hozon and Syfonex, are small, brass units that screw onto a faucet at one end and onto a hose at the other end. When water passes through a restricted orifice in the unit, a pressure difference is created between the waterline and the stock tank. This draws concentrated fertilizer solution into the faucet connection from the suction line to mix the solution with water in the hose (Figure 2).

These inexpensive injectors can be easily attached to any faucet but do not provide precise control over chemical application. Because of water pressure fluctuations, variable amounts of chemical may be injected into the hose. A minimum of 35 pounds per square inch of water pressure is needed for proper operation. In addition, the injector ratio is low, typically 1:16, and, therefore, requires either frequent replenishing of the stock solution or a large stock tank, thus limiting the use of Venturi-type injectors to small growing areas. A Hozon will draw 1 gallon of concentrate in about 5 minutes. This is mixed with



### Injector ratio 1:100

To get from ratio to percent:

$$(1/50) \times 100 = 2\%$$

To get from percent to ratio:

$$100 \div 2\% = 1:50$$

Injector ratios

$$1:50 = 2\%$$

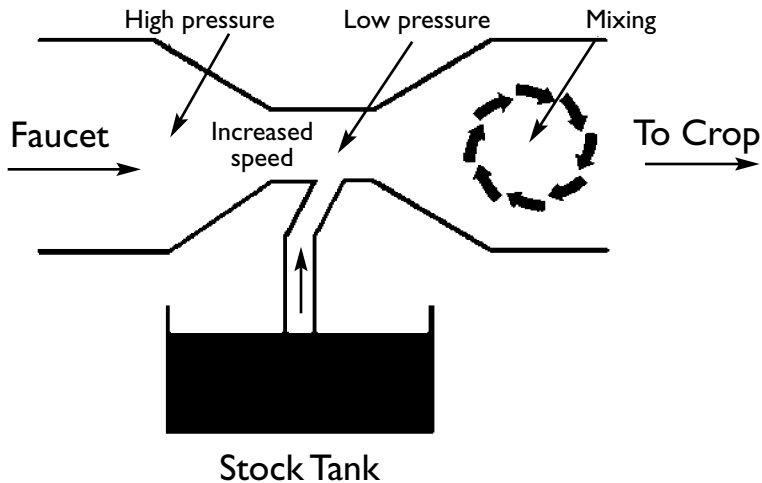
$$1:100 = 1\%$$

$$1:200 = 0.5\%$$

$$1:500 = 0.2\%$$

**Figure 1.** Injector ratios are expressed as percentages.

approximately 12 to 18 parts of water in the hose, depending on the flow rate. A larger diameter hose,  $\frac{3}{8}$  inch instead of  $\frac{1}{2}$  inch diameter, increases the flow rate. Excessive back pressure can cause the unit to stop siphoning. A Hozon should not be more than 50 feet from the hose outlet to work properly. If more than 50 feet of hose is required, connect the Hozon between two sections of hose. Besides fertilizer, a Hozon can be used to dispense insecticides, fungicides, and other water-soluble chemicals through a hose. A Hozon requires very little maintenance. Check the screen on the suction line for clogs and periodically remove fertilizer salt deposits from the mixing valve. Fertilizer mixing recommendations are in Table 1.



**Figure 2.** A Venturi-type injector uses pressure created between the waterline and the stock tank to draw concentrated fertilizer solution into the faucet connection from the suction line to mix the solution with water in the hose.

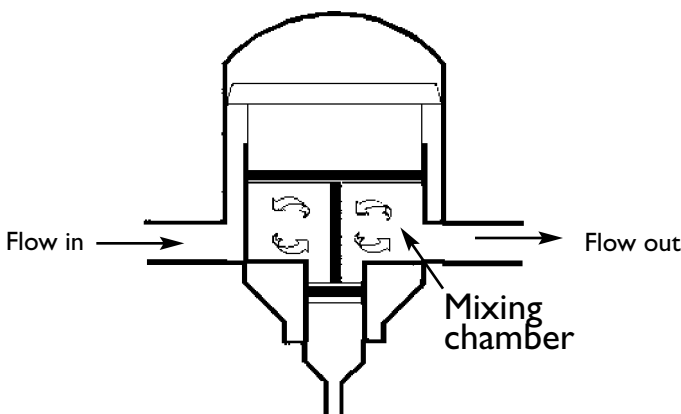
## Positive Displacement Injectors

Positive displacement injectors, such as Dosatron, DosMatic, Anderson, Smith, and Gewa products, provide consistent injector ratios for their designed flow rates over wide variations in water pressure. A measured amount of stock solution, determined by filling a specifically sized chamber, is injected into the irrigation water, which also is measured by the unit. In most cases, the limiting factor with these injectors is the minimum and maximum water flow rates permissible. However, the industry offers models that can accommodate a wide range of flow rates. The injector ratio depends on the size of the cylinders and the relative rate of displacement of fluid in the cylinders by the pistons. Precise control over the amount of injected chemicals, smaller stock tanks, and broader injector ratios has made positive displacement injectors an industry standard.

### Dosatron Injectors

Dosatron injectors operate without electricity, using water pressure as the power source. They are installed directly in the water supply line. Water drives the injector, which takes up the required amount of concentrate directly from a stock tank containing concentrate solution. Inside the injector, the concentrate is mixed with the water, and water pressure forces the solution downstream. The amount of concentrate is directly proportional to the volume of water entering the injector, irrespective of variations in water flow or pressure, which may occur in the main waterline (Figure 3).

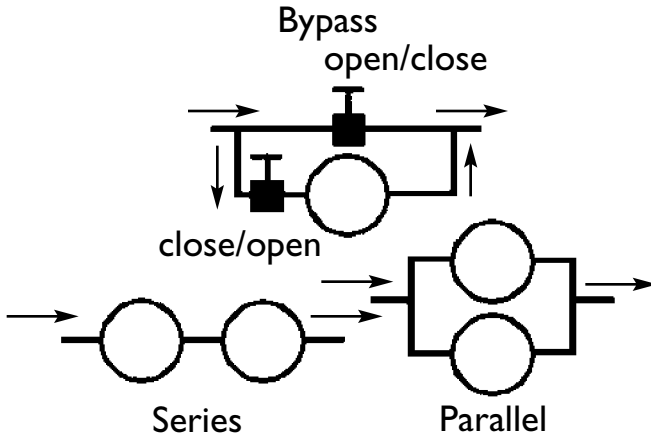
Maximum flow rates for Dosatron injectors range from 7 to 264 gallons per minute, with injector ratios from 1:50 to 1:500 for smaller flow rates to 1:50 to 1:500 or 1:1000 for larger flow rates, depending on the model. Injector ratio can be easily adjusted on the outside of the units. Recently, a unit allowing 1:3000 ratio has become available. Dosatron injectors can be installed in a variety of



**Figure 3.** Dosatron injectors use water pressure as the power source. The amount of concentrate is directly proportional to the volume of water entering the injector.

system configurations in addition to being put directly in the waterline. Special configurations allow bypassing with clear water, injecting multiple solutions (series), and increasing water flow (parallel) (Figure 4).

Standard Dosatron units allow for injection of most acids (depending on the concentration of the acid and water temperatures); however, the concentration of injected acid should not exceed 5 percent. Stronger acids can be injected if units have PVDF (Polyvinylidene Fluoride) parts or other options for injecting corrosive materials.



**Figure 4.** A permanently installed injector plumbed off the main waterline permits clean water to flow through the irrigation line.

### DosMatic Injectors

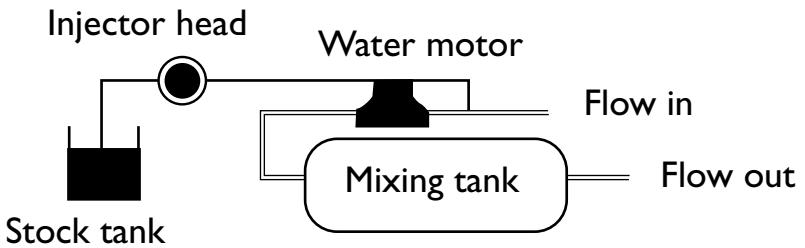
DosMatic injectors operate without electricity and use water pressure as the power source. They are installed directly in the water supply line. Water drives the injector, which takes up the required amount of concentrate directly from a stock tank containing concentrate solution. Inside the injector, the concentrate is mixed with the water, and water pressure forces the solution downstream. The amount of concentrate is directly proportional to the volume of water entering the injector despite variations in water flow or pressure, which may occur in the main waterline.

Maximum flow rates for DosMatic injectors range from less than 1 to 100 gallons per minute with injector ratios from 1:10 to 1:4000 depending on the model. The injector ratio can be adjusted while in use. A wide range of combinations of water flow and injector ratios can be accommodated, e.g., low flow and low injection, low flow and high injection, to high flow and low injection, and high flow and high injection. Standard DosMatic units allow for injection of most acids and disinfectants. Advantage models are specially designed for water pH adjustment, and others allow remote injection of chemicals downstream for in-series application.

## Anderson Ratio:Feeder Injectors

Anderson Ratio:Feeder injectors feature positive displacement rather than siphoning to pump the correct amount of chemicals into the waterline and volume proportioning by a flow-metered pump. Maximum flow rates for these injectors range from  $\frac{3}{4}$  to 3,000 gallons per minute at pressures of 15 to 125 pounds per square inch with low pressure loss. Injection accuracy is maintained over a wide range of flow and pressure ranges. Injector ratios can be set from 1:80 to higher than 1:200 depending on the model. The injector ratio can be adjusted while in operation.

Models in this line of injectors can have from one to many separate injection heads to allow for injection of multiple stock solutions. All models can handle a wide range of chemicals, including acids. Models are also available for small or large application and for stationary or portable installation. Many of the models require electricity, but you can use a rechargeable battery pack or solar cell. Ratio:Guard monitors and probes can be installed in-line on the outlet side of the injector for constant monitoring of pH and electrical conductivity of the chemical solution being delivered to crops. FertiCom JEPO computer software for the J Plus Series of injectors is available to automate up to 16 injectors with custom recipes, to monitor pH and electrical conductivity, and to log performance data (Figure 5).



**Figure 5.** Computer software for the J Plus Series of injectors can automate up to 16 injectors with custom recipes, monitor pH and electrical conductivity, and log performance data.

## Smith Measuremix Injectors

Smith Measuremix injectors rely on water passing through a water motor to provide the power to run the injector pump. The water motor actually meters the water running through the unit. The injector pump strokes once for every revolution of the water motor. The proportion of water to fertilizer solution remains the same, regardless of changes in water pressure. The Smith Measuremix is designed to dispense a variety of liquid chemicals. The water motor is made of bronze and stainless steel. The injector pistons are constructed of stainless steel on all models; valves and fittings in the injector system are stainless steel on standard models. The units are factory set at injector ratios of 1:100 or 1:200. Injector ratios of 1:50 and 1:150 are available on some models. Flow rates, which go up to 700 gallons per minute, allow simultaneous fertilization of numerous benches or an entire greenhouse range.

Models that accommodate flow rates higher than 200 gallons per minute have injector ratios of 1:800 to 1:4000. Some models are two-injectors-in-one and allow simultaneous injection of two chemical mixes. Smaller units, such as the model R-1, are designed for portable hand watering applications as well as permanent installation. They accommodate flow ranges from 2 to 12 gallons per minute. Constructed almost entirely of plastics, the R-1 can be used to inject any combination of liquid fertilizers, fungicides, chelates, insecticides, or mild acids. Virtually no maintenance is required except flushing the fertilizer out of the machine after each use. A drawback of this model is that if it malfunctions or is inaccurately injecting, it must be sent back to the factory for repairs.

## Gewa Injectors

The Gewa injector is manufactured in Germany and has been distributed in the United States since 1949. This injector has no suction or pumping device. The concentrated fertilizer solution is forced into the waterline by the water pressure. The fertilizer concentrate is poured inside the injector into a plastic membrane suspended inside the tank, and the lid is sealed shut. When the water is turned on, it surrounds the membrane and applies pressure to the bag, which forces a calibrated amount of concentrate into the waterline. During operation, the plastic bag on the inside of the Gewa folds down on itself. Because the fertilizer solution has a higher specific weight than water has, folding-in takes place from the top down. Be sure the center tube is in place during operation to prevent the membrane from sealing off the flow of solution. The only moving part in the Gewa is a float in the valve. This bronze, spring-loaded float measures water flow on the inlet side of the valve. A sudden loss in water pressure or flow does not affect the proportioning of the valve.

Gewa injectors are available in sizes from 4- to 26-gallon capacity. Injector ratios range from 1:20 up to 1:300, depending on the model, and are accurate within 4 percent. A thick steel tank makes up the bulk of the Gewa. A water flow rate of 1.6 to 88 gallons per minute and water pressures up to 125 pounds per square inch are accommodated. Maintenance on a Gewa is higher than on



other injectors. Wheels are provided to make the injector easy to move. Periodically, the inner membrane must be replaced, which requires disassembling the unit. Be careful when opening and closing the Gewa so the top cover is not improperly closed or bent.

Contact information for individual injector manufacturers is in Table 2 at the end of this publication.

## Choosing an Injector

Consider several important factors when choosing an injector:

**Size of the operation:** Operations of up to 10,000 square feet can be serviced with small units.

**Type of fertility programs:** Base the fertility program on the types of crops grown, nutrient requirements of individual crops, and number of different species. Consider potential future expansion since it will be more economical initially to choose a larger unit than to replace a smaller one later.

**Water flow rate** (See calculation of water flow rate on page 16.): One of the first questions to consider when selecting an injector is the water flow rate range. The flow rate falls into three categories: low (0.05 to 12 gallons per minute), medium (12 to 40 gallons per minute), or high (more than 40 gallons per minute). Example, a 10-gallon per minute flow rate will service only one  $\frac{3}{4}$ -inch pipe and, thus, will fertilize only one bench of plants at a time. If this is the maximum water available from the water supply, a low flow rate injector is adequate. If water flow is not a problem, use as the main factor the amount of bench or ground area to be fertilized simultaneously. Factors to consider, including the size of the operation, are as follows:

- Minimum and maximum areas to be watered at a time
- Amount of fertilizer solution required for each square foot of bench or ground area
- Time needed to deliver the fertilizer solution

If the area to be fertilized is 100 to 10,000 square feet and the solution required is  $\frac{1}{4}$  gallon per square foot for 10 minutes, then 25 to 25,000 gallons must be delivered in 10 minutes or 2.5 to 250 gallons per minute.

**Injector ratio:** This is the second question to consider. Having an adjustable injector ratio is desirable because a single fertilizer concentrate can be applied at different concentrations to crops with varying nutrient requirements. Injector ratios fall into four ranges: very low (1:4000 to 1:250, 0.025 percent to 0.4 percent), low (1:500 to 1:100, 0.2 percent to 1 percent), medium (1:200 to 1:100, 0.5 percent to 1 percent), high (1:100 to 1:20, 1 percent to 5 percent), or highest (1:50 to 1:10, 2 percent to 10 percent). A low injector ratio means a small portion of concentrated solution is injected into the irrigation line; a high injector ratio means a large portion of concentrated solution is injected into the line. Low injector ratio also means a highly concentrated stock solution. A word of caution: with ratios more than 1:200, incomplete dissolution of fertilizer may

occur, as maximum solubility is exceeded. For greenhouse operations, injector ratios of 1:200 or lower are recommended.

**Water pressure:** The water pressure required for proper operation of the injector is measured in pounds per square inch, or Psi. If the water pressure is lower than recommended for the injector, it will not work properly.

**Water quality:** Solid particles in the water supply act as abrasives and wear away the water-measuring mechanism in the injector. If you have problems with suspended solids, install a filter upstream of the injector, and place pressure gauges before and after the filter. The difference in pressure readings indicates when the filter requires cleaning.

Water pH and alkalinity are both important factors to consider not only when selecting an injector but also when planning a fertility program. A pH reading is a measurement of the acidity or basicity of the solution and indicates the concentration of hydrogen ions. The range is 0 (most acid) to 14 (most basic). The recommended range of irrigation pH depends on the crop grown but generally is 5.4 to 7.0. Alkalinity is a total measure of the substances in water that have acid-neutralizing ability. Two ways to think of alkalinity are that it is the buffering capacity of water and that it is like lime in the water. Alkalinity should not be confused with pH, however. While the pH of a solution is the concentration of hydrogen ions and measures the strength of an acid or a base, alkalinity reflects the solution's power to react with acid and buffer the solution pH.

The alkalinity concentration has far reaching implications because of its strong effect on the potting media pH. Of two water sources, one with a pH of 9.0 and alkalinity of 50 and the other with a pH of 7.0 and alkalinity of 300, the first will raise potting media pH *very little*, while the second will raise potting media pH *quickly*. Judgment of the quality of the two water sources would be wrong if based on the pH alone and correct if based on the alkalinity concentrations.

High alkalinity water can be corrected by injecting acid in the water. This is when the correct choice of an injector is important. To determine if you would need acid injection, send a water sample from your water source or sources to a commercial or institutional laboratory and request a pH, alkalinity, and water hardness test. Analyze your water regularly. Recommendations are to obtain a water analysis as follows:

- Every time a new water source is added
- At least twice a year, once during the dry season and once during the rainy season
- As often as every 3 months

See Extension publication ANR-1158, "Water Quality Management for Greenhouse Production," for more information on water quality.

**Stock tank size:** Base stock tank size on injector ratio and daily water usage. The stock tank should be large enough to allow the entire fertilization job to be completed with one batch of fertilizer concentrate. A large stock tank

is needed if low injector ratios are used and if the injector is used frequently. A larger stock tank size is beneficial if a constant liquid fertilization program is practiced.

**Chemicals being injected:** This is a particularly important consideration if acid injection is required. If you will be injecting acid to reduce alkalinity and water pH, make sure the injector selected is equipped to handle acid injection and be sure of the acid concentration to be used. Use injectors with stainless steel parts or other options for injecting corrosive chemicals. The choice of an injector also should be made based on the type of acid used. Example, for a sulfuric acid injector, the parts that come in contact with the acid must be made of acid-resistant rubber, while for a phosphoric acid injector, these same parts must be made of stainless steel. If pesticides and insecticides are to be injected on a consistent basis, the unit should contain no plastic parts because many insecticides and fungicides contain a hydrocarbon base (emulsions) that are harmful to PVC plastics.

**Multiple injection heads** (for incompatible chemicals): It is desirable to have the ability to inject several fertilizers at the same time that cannot be mixed in the same stock tank. Example: a recommendation says to apply calcium nitrate to a crop. Phosphorus also needs to be supplied, so you need to inject ammonium phosphate. However, if these two chemicals are mixed in the same stock tank, the calcium will combine with phosphate and precipitate out of solution as calcium phosphate. Therefore, an injector with dual heads is required to apply both fertilizers at the same time from two separate fertilizer stock tanks. Precipitation will not occur in this case because the fertilizers do not mix until after they are diluted to final concentration. A similar situation occurs when magnesium sulfate (Epsom salts) is mixed in the same tank with calcium nitrate. Commonly encountered precipitation incompatibilities occur when these chemicals are placed in the same tank:

- Sulfates and calcium. *Result:* calcium sulfate, gypsum.
- Phosphates and calcium. *Result:* calcium phosphate.
- Phosphates and iron. *Result:* iron phosphate.
- Potassium bicarbonate and other fertilizers. *Result:* the bicarbonate may raise the pH high enough to cause precipitation of other fertilizer ingredients.

**Multiple parallel injectors:** In some situations, being able to fertilize a few plants at a low flow rate is just as important as being able to irrigate a large crop at a high flow rate. For these situations, more than one injector can be connected in parallel. This increases the maximum flow rate by the sum of the connected injectors while maintaining the low minimum flow rate from one injector. For example, an injector with a 20- to 100-gallon per minute flow rate range connected in parallel would deliver these rates while maintaining a low minimum flow rate: 2 injectors = 20 to 200 gallons per minute range or 3 injectors = 20 to 300 gallons per minute range.

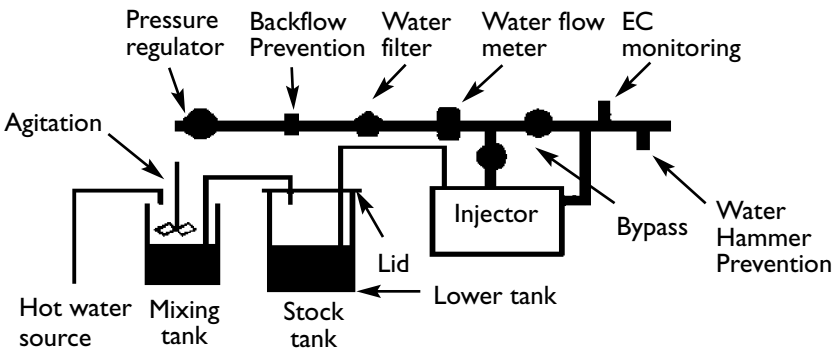
**Portable or stationary injectors:** With small operations, it is convenient to be able to move the injector unit around, while with large operations where high volumes of fertilizer solution are regularly used at each fertilization, stationary injectors along with large stock tanks are more appropriate. In large greenhouse operations divided into several greenhouse sections, growers often install an injector in each section so different fertilizer programs can be used for different crops.

**Ease of repair and longevity of the unit:** If the repair cost is equal to half or more of the cost of a new unit, replacement of an existing injector is advised. In the case of small injectors, keep a backup unit available to put into service in case the original unit malfunctions and must be sent to the manufacturer for repairs.

**Manufacturer's reliability, technical support, service, and other qualifications:** Many manufacturers have World Wide Web sites with useful information about their products (Table 3). Attend trade shows and talk to company representatives about the full range of their products and their features.

## Installing an Injector

A permanently installed injector should be plumbed off the main waterline (water bypass), which will permit clean water to flow through the irrigation line to purge the line of fertilizer solution or supply water to crops when fertilizer is not needed (Figure 4). A bypass installation also allows easy removal of the unit in case of malfunction or the need for maintenance. Consider installation of additional equipment for optimal performance (Figure 6), including the following:



**Figure 6.** Additional equipment can be added for optimal performance.

- A 140- or 200-mesh filter upstream of the injector unit.
- A pressure regulator if in-line water pressure exceeds the maximum allowable for the unit.
- A one-way check valve against water hammer. (See discussion of water hammer in this publication).
- A back flow valve to prevent contamination of the irrigation water supply if negative pressure occurs. These may be mandated by state or local laws.

Some injectors come with an optional electrical conductivity meter for installation in the line after the injector. This makes it easy to determine whether the injector is functioning properly. Maintenance of the probes on these meters is essential to obtain correct readings.

A post-injector blend tank may be needed to ensure good mixing of water and chemicals. Whether a blend tank is needed depends on the type of injector, the size of the injector, and the design of the irrigation system.

Security is often an issue for large, stationary injectors. Avoid installing a stationary injector in a greenhouse or any other openly accessible area. Choose a small room with enough space for the injector, a reasonable amount of fertilizer, and equipment for mixing. Keep the injector room locked and provide keys only to those who need access. Do not store any pesticides in the injector room.

## **Water Hammer**

Water hammer is energy in the water that is traveling in one direction, hits a closed valve, such as a solenoid, and ricochets back in the line at four times the original pressure. If the water pressure is 50 pounds per square inch in the waterline, four times that would be 200 pounds per square inch. This affects the injector and may damage it. Water hammer can be a serious problem in installations with long pipe runs or where solenoid valves are used. Water hammer can generate pressures up to 500 pounds per square inch or more! This puts stress on the whole injector and on the entire water system, but it is especially destructive to injectors with diaphragms. To avoid this, install a simple check valve or if you have water pressure more than 50 pounds per square inch, install an accumulator (captive air device) on the outlet side of the injector.

## **Using an Injector**

The injector ratio should be known and adjusted as needed (see calibration methods on page 17). If large deviations (more than 5 percent) from the expected setting occur, contact the manufacturer for possible repair, replacement, or maintenance.

Water-soluble fertilizers should be dissolved completely; use hot water if necessary but allow the solution to cool before starting the injector. Injector ratios higher than 1:200 require highly concentrated stock solutions; fertilizer

may not dissolve completely if it exceeds the maximum solubility. Tracer dye in water-soluble fertilizers should not be used as an indicator of a solution's concentration. Different fertilizer lots may have a different dye content causing variability in color intensity of fertilizer solutions. Before mixing different chemicals for the injector, the chemical manufacturers should be consulted to determine the compatibility of their products. Constant agitation is needed when applying wettable powders because they suspend but do not dissolve in water. Check with the injector manufacturer to be sure your injector can handle wettable powders. Some types can abrade internal components.

## **Acid Injection**

Potential acidity or corrosiveness of the chemicals should be taken into account, especially if acid injection is needed. Use extreme caution with acid injection. With some standard model injectors, acid concentrations should not exceed 5 percent. Selection of a particular acid depends on the acid concentration and water temperature. As temperatures increase, so does the speed of acid reactivity. Always have baking soda available when using acids. If you come in contact with acid, quickly cover the acid with a generous amount of baking soda to neutralize the acid and minimize injuries.

## **Stock Tanks**

Stock tanks should be opaque. The chelating agents in fertilizer, which help make micronutrients available to the plants, break down if exposed to light. Cover stock tanks to prevent algae or debris buildup and contamination or evaporation of stock solution. If debris buildup occurs, it may plug the injector intake and cause less than the required amount of stock solution to be siphoned. The result will be low fertility crops. If the stock tank is left uncovered, some evaporation will occur, increasing the concentration of the stock solution. The result will be high fertility, possible high soluble salt damage, and nutrient toxicities in the crops. Undissolved fertilizer salts can accumulate in the bottom of the stock tank, which results in large differences in fertilizer concentration. If a large stock tank is used, make sure that the stock solution is mixed well before using it. A good solution is to have a separate mixing tank equipped with a mechanical or pneumatic agitator, where the concentrated fertilizer solution is dissolved. If any residue forms, it falls to the bottom of the tank. Then siphon from the mixing tank into a stock tank that will be used for injector intake. Position the stock tank at a lower level than the injector is positioned to prevent back-siphoning of fertilizer into the waterline when the injector is inactive.

## Maintaining an Injector

The intake strainer should be suspended 2 to 4 inches above the bottom of the stock tank to avoid siphoning undissolved concentrate. Never let the suction tube filter lie on the bottom of the stock tank. The strainer on the suction tube should be inspected regularly for clogs or cracks and cleaned with water. Regardless of the type of injector used, always inject clean water after the injector has been used. The stock tank should be cleaned regularly (weekly or bi-weekly, depending on frequency of use) to prevent dirt and scale buildup. Inspect and service injector O-rings. Petroleum-based lubricants, such as Vaseline, lanoline, WD-40, or motor oil, should not be used on injector dosage pistons or seals. Silicon-based lubricants can be used.

If an injector will not be used for an extended period, it should be removed from service. The system should be flushed with clean water, either by pumping water through the unit (if not delivering acid) before removing it or by rinsing these parts after removal. The valve openings should be taped closed while still wet. This will protect the seals and prevent insects from plugging the openings. When the injector is removed from service, it should be drained completely to prevent damage by water freezing inside.

## Checking Water Flow Rate

**Water meter method:** Water flow rate can be measured easily if a water flow meter is installed. Turn the irrigation system on full and read the meter at a noted time. Take a second reading after the water has run for several minutes. Convert the difference between the beginning and ending meter readings from cubic feet, the typical water meter unit, into gallons by using the following formula:

$$\text{rate of flow} = 7.5 \times [\text{meter B} - \text{meter E}] \div [\text{E minutes} - \text{B minutes}]$$

where, rate of flow is expressed in gallons per minute, meter B is the beginning meter reading, meter E is the ending meter reading and minutes is duration of the test.

**Open container method:** If the water supply flows through a single orifice, a suitable container can be used to measure the water flow rate. Turn the water flow on full and time how many minutes it takes for the tank to fill. Divide the capacity of the tank in gallons by the number of minutes to obtain flow in gallons per minute.

# Calibrating an Injector

Periodic calibration is needed to ensure that an injector is operating properly. Use one of the following methods for a quick check of the final fertilizer concentration while it is in operation and then to distinguish a fertilizer mixing error from an injector malfunction.

**Volume ratio method:** One way to determine if an injector is delivering at the correct injector ratio is to directly measure the fertilizer concentrate input volume and dilute fertilizer output volume. The ratio of the input volume to the output volume should equal the injector ratio set on the injector. This process is carried out as follows:

- Begin by operating the injector at a rate normally used to fertilize crops.
- Place the injector siphon tube in a graduated container, such as a measuring cup or graduated cylinder, containing a measured volume of water.
- Discharge fertilizer solution from a hose into a large container, such as a trash can, until the graduated container is about half empty.
- Measure the uptake volume from the graduated container and the output volume in the large container. The uptake volume from the graduated container is the original volume minus the volume remaining in the graduated container.
- The ratio of the graduated container uptake volume to the large container volume should about equal the injector ratio setting. Determine the dilution ratio using the following formula:

$$\text{injector ratio} = \text{output volume} \div \text{input volume}$$

where, output volume is the known amount of fertilizer solution after it has passed through the injector, and input volume is the amount of concentrated fertilizer solution that was taken up by the injector during the test.

Keep in mind that this method determines if the injector is mixing the concentrated stock solution with water in the line at the correct injector ratio, i.e., correct mechanical function. It cannot determine if the final concentration of fertilizer delivered to the crops is correct. Errors in calculating the amount of fertilizer to mix with water, errors in weighing the fertilizer, and residues from previous fertilizers in the stock tank can result in incorrect final fertilizer concentrations that this method cannot detect. A disadvantage of this method is that it is inconvenient to use for quick checks of injector function because it involves large volumes of water especially with injectors set at high injector ratios, i.e., 1:200 and higher.

Example: The injector is set for a 1:50 ratio. If (in the above test) 370 milliliters of concentrate was used to make 5 gallons (18,925 milliliters) of diluted solution, the actual ratio is  $18,925 \div 370 = 51$ .



This is close to expected, being off by only 1 percent. Repeat this test several times.

You should also check your injector manual for other ways to test your specific brand.

**Electrical conductivity measurement:** This easy method of measuring electrical conductivity is commonly used for water-soluble fertilizers. It does not require collection of a large quantity of fertilizer solution, and it is an excellent means of periodically monitoring the fertilizer injector while in operation. The critical element for this method is to follow precisely the fertilizer manufacturer's guidelines for mixing concentrated solutions. Fertilizer suppliers generally provide charts with electrical conductivity readings of various concentrations of water-soluble fertilizer solutions. When measuring the required quantity of fertilizer (usually given as a weight amount), use a scale to ensure the proper amount. Using other measuring means, such as coffee cans, plastic cups, etc., results in erroneous electrical conductivity reading due to variability in the fertilizer quantity used to make up the concentrated solution. Only reliable, calibrated conductivity meters should be used to ensure accuracy of the readings. Standardized conductivity solutions are available from the measuring device manufacturer and should always be used to calibrate the meter. It is very important to keep the electrical conductivity meter in good working order (i.e., change the batteries as needed) to get correct results. This process is carried out as follows:

- Start the test by collecting and testing a sample of clear irrigation water. Dissolved salts in well or pond water and high alkalinity can raise the water electrical conductivity. Let the water run for a few minutes to flush previous residues from the pipes before collecting the sample. Rinse the sample container and electrode three times with the clear water, then fill the sample container to a level that covers the meter electrode. Measure the electrical conductivity of the water sample and record it.
- Turn the injector on and run it for a few minutes to let the fertilizer concentration stabilize before collecting a sample. Rinse the sample container and electrode three times with the fertilizer water, then fill the sample container to a level that covers the meter electrode. Test and record the electrical conductivity of the fertilizer solution. Calculate the electrical conductivity contributed by the fertilizer using the following formula:

$$\text{EC FERTILIZER} = \text{EC FERTILIZER SOLUTION} - \text{EC IRRIGATION WATER}$$

Compare this reading to a chart on the fertilizer bag label.

Example: If the injector is set for a 1:50 ratio, 10.1 ounces of 20-10-20 fertilizer for each gallon of stock solution is used at a concentration of 300 parts per million nitrogen. If (in the above test), the  $\text{EC}_{\text{IRRIGATION WATER}}$  is 0.3 mmhos/cm and the  $\text{EC}_{\text{FERTILIZER SOLUTION}}$  is 2.1 mmhos/cm, the actual  $\text{EC}_{\text{FERTILIZER}}$  is  $2.1 - 0.3 = 1.8$  mmhos/cm.

The technical chart for this particular fertilizer lists the expected electrical conductivity for 300 ppm nitrogen at 1.86 mmhos/cm. Therefore, the actual dilution ratio is incorrect by a factor of about 3 percent  $(1 - (1.8 \div 1.86)) \times 100$ .

Regular testing of the fertilizer electrical conductivity is an effective means of monitoring injector performance. Make sure to calibrate your electrical conductivity meter before using it. If you don't calibrate your injector, you will get poor results and make the wrong decisions concerning your fertilizer program.

## Fertilizer Calculations

Commercially available water soluble fertilizers are combinations of fertilizer salts called fertilizer carriers. A portion of fertilizer carriers is made up of essential nutrients for plant growth while the rest is non-nutritive. Commercial fertilizers used in greenhouse production come in a wide variety of formulations. Complete fertilizers contain the three primary macronutrients: nitrogen, phosphorus, and potassium in various proportions, such as 20-10-20. Fertilizer packages are labeled with three numbers. The first indicates the percentage of actual nitrogen (N); the second, the oxide form of phosphorus ( $P_2O_5$ ); and the third, the oxide form of potassium ( $K_2O$ ). Other commercial fertilizer formulations may lack one of the three primary macronutrients, most commonly phosphorus, e.g. 15-0-15. Micronutrients may or may not be included as part of a commercial fertilizer.

Fertilizer recommendations for greenhouse crops are given as either parts per million (ppm) of a specific fertilizer nutrient or as pounds and ounces (weight basis) of a fertilizer formulation per 100 gallons of water. Recommendations reported as weight of a fertilizer formulation per 100 gallons in final solution are easy to prepare as long as the stock tank size and injector ratio are accounted for. However, one problem with recommendations on a weight basis is that the concentration of a specific fertilizer nutrient is not readily apparent. Therefore, comparing fertilizer recommendations or utilizing different fertilizer formulations for the same recommendation are difficult. For example, which fertilizer solution contains the most nitrogen, one with 6 pounds 20-10-20 per 100 gallons or one with 8 pounds 15-15-15 per 100 gallons? The answer is not readily apparent for a rate given on a weight basis.

Recommendations based on parts per million specify the exact concentration of a specific fertilizer nutrient to apply. A part per million is one part of a pure substance dissolved into one million parts of another pure substance. Preparing and applying fertilizer on a parts per million basis has one advantage: it takes into account that different fertilizer formulations have different quantities of nitrogen, phosphorus, and potassium. Therefore, 200 ppm nitrogen may be applied using either a 20-10-20 or a 15-15-15 formulation. A recommendation given on a parts per million basis presents a problem in that parts per million is not something that can be weighed. In addition, parts per million is a metric unit that must be converted to English units.

Both types of recommendations are final concentrations for crop application and do not specify how much fertilizer to mix for a given stock tank size or injector ratio. Therefore, how many pounds and ounces of a fertilizer must be added to the stock tank at a given injector ratio? The answer involves converting parts per million to a weight per 100 gallons basis, then adjusting the rate for the stock tank size and the injector ratio. Begin by gathering the following information:

- Determine the recommended fertilizer rate for the crop grown.  
Example: 200 ppm nitrogen
- Determine which fertilizer formulation to use and its analysis.  
Example: 20-10-20
- Determine the injector ratio for the fertilizer injector to be used.  
Example: 1:100
- Determine the size of the fertilizer stock tank in gallons.  
Example: 25 gallons

### **Weight Basis**

Example: Crop production literature on chrysanthemum production recommends that a 20-20-20 fertilizer formulation be applied at a final concentration of 16 ounces per 100 gallons of water. How much fertilizer should be mixed in a 25-gallon stock tank if an injector with a 1:30 injector ratio will be used?

Step 1: Adjust the rate for the stock tank size using the following general equation:

$$\frac{\text{ounces per 100 gallons}}{100 / \text{stock tank size (gallon)}} = \text{ounces fertilizer per stock tank}$$

$$\frac{16.0 \text{ ounces per 100 gallons}}{100 / 25 \text{ gallons}} = 4.0 \text{ ounces 20-20-20 per 25 gallons}$$

Step 2: Adjust the rate for the injector ratio. Because the injector will inject 1 gallon of fertilizer concentrate into every 29 gallons of water passing through the waterline, the stock solution must be 30 times more concentrated to achieve the desired concentration at the end of the hose as follows:

$$\text{ounces per stock tank} \times \text{injection ratio} = \text{ounces per stock tank using injector}$$

$$4.0 \text{ ounces per 25 gallons} \times 30 = 120.0 \text{ ounces per 25 gallons using a 1:30 injection ratio}$$

### **Parts Per Million Basis**

Example: A greenhouse magazine article recommends the application of 150 ppm nitrogen using a 20-10-20 for marigolds. How much fertilizer must be mixed in a 25-gallon stock tank using a 1:100 injector?

Step 1: Convert the ppm recommendation to a weight basis using the following equation:

$$\frac{\text{desired ppm}}{\text{percentage of nitrogen} \times 0.75^*} = \text{ounces of fertilizer per 100 gallons}$$

$$\frac{150 \text{ ppm}}{20 \text{ percent} \times 0.75} = 10.0 \text{ ounces 20-10-20 per 100 gallons (final solution)}$$

\* Where did 0.75 come from? (Figure 7)

**The rule of 75**

1 ounce per 100 gallons = 75 ppm

**Where did this come from?**

One ounce (28.35 grams) of any pure dry substance that will dissolve 100% in a volume of 100 gallons of water equals 75 ppm

**1 ounce = 28.35 grams or 28,350 milligrams**  
**28,350 milligrams ÷ 378 liters = 75 ppm**  
 (1 gallon = 3.78 liters or 100 gallons = 378 liters)

**Figure 7.** The rule of 75

Step 2: Adjust the rate from step 1 for the stock tank size (25 gallons) using the following general equation:

$$\frac{\text{ounces per 100 gallons}}{100 / \text{stock tank size (gallons)}} = \text{ounces fertilizer per stock tank}$$

$$\frac{10.0 \text{ ounces per 100 gallons}}{100 / 25} = 2.5 \text{ ounces 20-10-20 per 25 gallons}$$

Step 3: Adjust the rate from step 2 for the injector ratio. Because the injector will inject 1 gallon of fertilizer concentrate into every 99 gallons of water passing through the waterline, the stock solution must be 100 times more concentrated to achieve the desired concentration at the end of the hose as follows:

$$\text{ounces per stock tank} \times \text{injection ratio} = \text{ounces per stock tank using injector}$$

$$2.5 \text{ ounces per 25 gallons} \times 100 = 250.0 \text{ ounces per 25 gallons using a 1:100 injector ratio}$$

Step 4: At this point, it may be more useful to convert ounces to pounds and ounces in the following:

**16 ounces = 1 pound (dry) ∴ 250.0 ounces per 25 gallons / 16 ounces = 15 pounds 10 ounces 20-10-20 per 25 gallons for 150 ppm nitrogen**

Useful metric to English conversions are in Table 3.

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## Appendix

**Table 1.** Ounces of Different Types of Water-Soluble Fertilizer Needed to Make 1 Gallon of Concentrate for Use With a Hozon Injector

	parts per million nitrogen desired				
Fertilizer	100	150	200	250	300
10-30-20	2.0	3.0	4.0	5.0	6.0
15-30-15	1.35	2.03	2.70	3.38	4.05
20-20-20	1.0	1.5	2.0	2.5	3.0

Example: If a fertilizer recommendation is 2 tablespoons per gallon final concentration, make the solution 16 times greater than the 2 tablespoons rate (i.e., 16 x 2 = 32) so 32 tablespoons per gallon is the stock tank rate. When mixed with water by the Hozon injector, the solution will come out the hose end at the recommended rate of 2 tablespoons per gallon.

**Table 2.** Fertilizer Injector Companies and How to Contact Them

Company name	Phone number	Web site
Dosatron International, Inc.	800-523-8499	www.dosatronusa.com
DosMatic U.S.A. Inc.	800-344-6767	www.dosmatic.com
H.E. Anderson Co.	800-331-9620	www.heanderson.com
Smith Precision Products Gewa	805-498-6616	www.smithpumps.com
(Brushking, U.S. distributor)	800-321-5667	www.loosnaples.com/bk/

**Table 3.** Useful Metric Conversions

To convert from	To	Multiply by
Gallons	milliliters	3,785
	cubic feet	0.134
	liters	3.78
Grams	ounces	0.03
Liters	fluid ounces	33.8
	quarts	1.06
	gallons	0.264
Ounces (dry)	grams	28.35
Ounces (liquid)	milliliters	29.6
	liters	0.03
Pints (liquid)	milliliters	473
	liters	0.473
Pounds	grams	453.6
Quarts (dry)	cubic inches	67.2
Quarts (liquid)	milliliters	946
	liters	0.946



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**For more information**, call your county Extension office. Look in your telephone directory under your county's name to find the number.

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2M, **New May 2004**, ANR-1243