CIR864

Chemical Injection Methods for Irrigation[1]

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METHODS OF CHEMICAL INJECTIONS

Chemical application through irrigation systems is called chemigation. Chemigation has been practiced for many years especially for fertilizer application (fertigation). In recent years, other chemicals are also being applied through irrigation systems with increasing frequency. The primary reason for chemigation is economy. It is normally less expensive to apply chemicals with irrigation water than by other methods. The other major advantage is the ability of applying chemical only when needed and in required amounts. This "prescription" application not only follows plant needs much closer than traditional methods, but also minimizes the possibility of environmental pollution. Through chemigation, chemicals can be applied only in amounts needed and thus large quantities are not subject to leaching losses if heavy rainfalls follow applications. Additional advantages of chemigation include less operator hazard and possibly reduced amounts of chemicals.

There are several methods of chemical injection into an irrigation system. These methods can be classified into four major groups: centrifugal pumps, positive displacement pumps, pressure differential methods, and methods based on the venturi principle. These four groups can be farther subdivided into specific methods (see Figure 1). In addition, some injectors use a combination of these methods. This publication will discuss each group of chemical injectors, their applications, and advantages and disadvantages. A summary of advantages and disadvantages of injectors discussed in this publication is presented in Table 1.

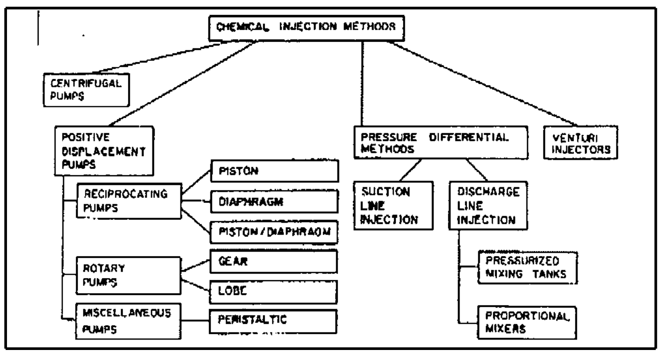

Fig. 1. Classification of chemical injection methods for irrigation systems.

CENTRIFUGAL PUMPS

Small radial flow centrifugal pumps (booster pumps) can be used to inject chemicals into irrigation

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systems. The principle of operation of a centrifugal pump is described in detail in IFAS Extension Circular 832. Basically, fluid enters the centrifugal pump near the axis of the high-speed impeller, and by centrifugal force is thrown radially outward into the pump casing. The velocity head imparted to the fluid by the impeller is converted into pressure head by means of volute or by a set of stationary diffusion vanes surrounding the impeller (Figure 2).

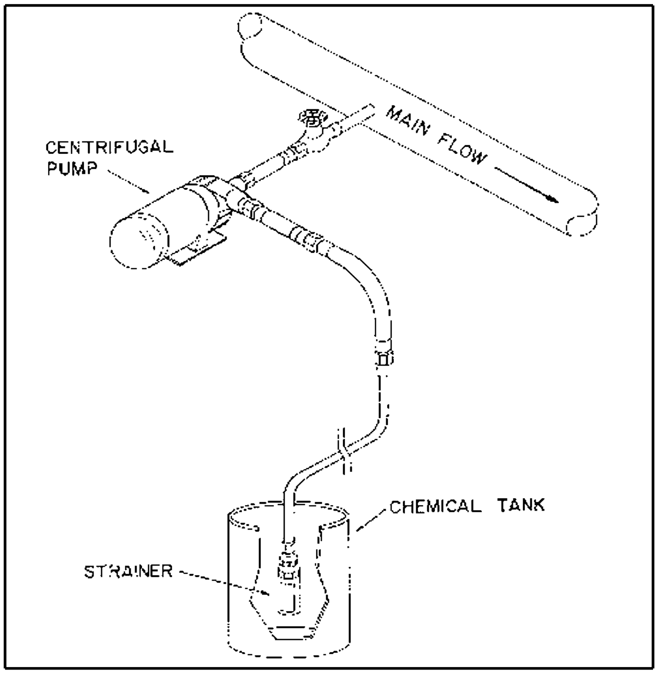

Fig. 2. Centrifugal pump chemical injector.

For a centrifugal pump to operate as an injector, it is necessary that the pressure produced by the pump be higher than the pressure in the irrigation line. However, the flow rate of the chemical from the pump depends on the pressure in the irrigation line. The higher the pressure in the irrigation line the smaller the flow rate from the injection pump. Because of that, centrifugal pumps require calibration while operating. It is also not recommended that this type of pumps will be used for the injection of toxic chemicals where the injection rate must be controlled very precisely.

POSITIVE DISPLACEMENT PUMPS

Positive displacement pumps are frequently used for injection of chemicals into a pressurized irrigation system. Positive displacement pumps are classified as reciprocating, rotary and miscellaneous types (Figure 1) depending on the mechanism used to transfer energy to the fluid. Reciprocating pumps include piston, diaphragm and combination piston/diaphragm pumps all commonly used for chemical injection into irrigation systems. Most rotary and miscellaneous pumps are not used for chemical injections and are not discussed in this publication. The exceptions are gear and lobe rotary pumps which are occasionally used, and peristaltic pumps which can be used when only small injection rates are required. Therefore, gear, lobe and peristaltic pumps will be discussed briefly in this publication. An interested reader is referred to IFAS Extension Circular 826 for a detailed description, typical applications and discussion of advantages and disadvantages of the various positive displacement pumps used in agriculture.

By definition, a positive displacement pump moves a certain, constant volume of fluid from the intake side of the pump to the discharge side of the pump. Theoretically, the volume displaced by the pump should be independent of the pressure encountered at the discharge point. However, this is not necessarily true for all pumps classified as positive displacement pumps. If the internal parts of the pump can deform due to the increased pressure (as in a mechanically driven diaphragm pump) the displacement volume of the pump will change and the injection rate will not be constant. Excessive pressure at the discharge may also result in some back flow through the clearances of the pump parts (for example, between the gears and the housing in the gear pump). Piston, fluid filled diaphragm, and piston/diaphragm pumps come closest to being ideal positive displacement pumps and to providing a constant flow rate independent of the discharge pressure. However, even with these pumps, excessive discharge pressures should be avoided (for example, due to a closed valve in a discharge line) because excessively high pressures may result in pump or line damage.

Reciprocating Pumps

Reciprocating pumps are pumps in which a piston or a diaphragm displaces a given amount of chemical with each stroke. The change in internal volume of the pump creates high pressure, which forces chemical into the discharge pipe. These pumps are classified as piston pumps, diaphragm pumps or a combination of piston and diaphragm.

In most of diaphragm, piston, and diaphragm/piston combination pumps the rotary motion of a drive wheel is transformed into reciprocating motion of a cylinder or a diaphragm.

The operation of a piston pump is similar to the operation of the cylinder of an automobile engine. On an intake stroke (Figure 3a), the chemical enters the cylinder through the suction check valve. On a compression stroke (Figure 3b) the chemical is forced into the discharge line through the discharge check valve.

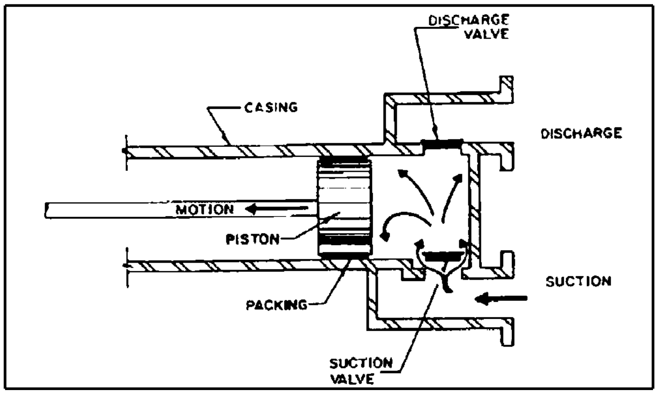

Fig. 3a. Piston pump - suction stroke.

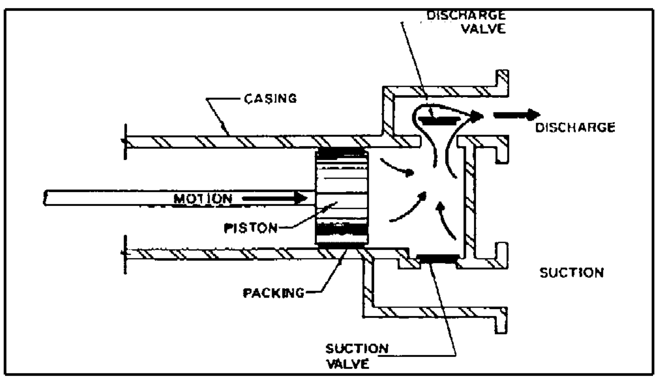

Fig. 3b. Piston pump - discharge stroke.

The operation of a diaphragm pump is similar to that of a piston pump. The pulsating motion is transmitted to the diaphragm through a fluid or a mechanical drive, and than through the diaphragm to the chemical being injected (Figure 4a and Figure 4b).

Combination pumps usually contain a piston that forces oil or other fluid against a diaphragm which displaces the concentrated chemical. The advantage of these pumps is that they combine the high precision of a piston pump with the resistance to chemicals characteristic of diaphragm pumps.

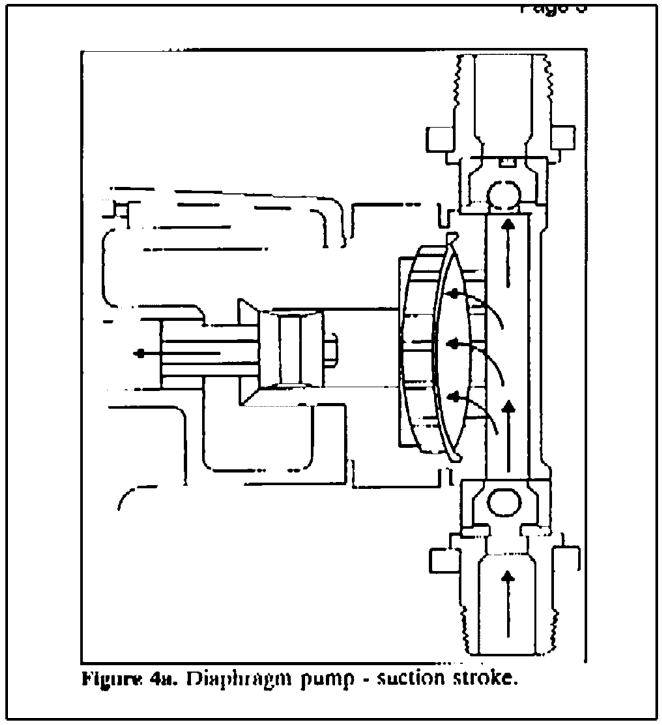

Fig. 4a. Diaphragm pump - suction stroke.

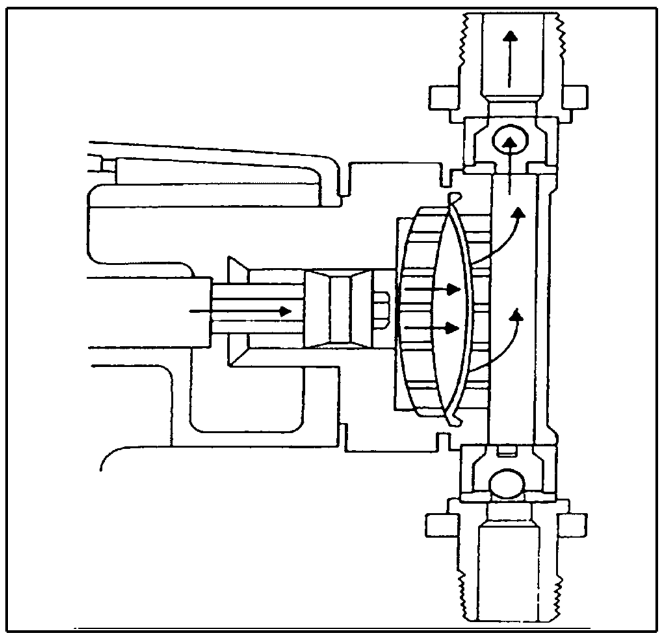

Fig.4b. Diaphragm pump - discharge stroke.

Reciprocating pumps are often electrically driven. The chemical injection rate from an electrically driven pump is approximately constant regardless of the water flow rate. Thus, the injection rate, must be adjusted between zones if the flow rate is not constant to all zones.

To assure constant concentration of chemical in the irrigation line an electrically driven injector can be equipped with a water flow sensor to detect changes in flow rate and automatically adjust the speed of the injector or injection time. The other possibility is to measure the conductivity of the irrigation water (if fertilizers are being injected) and use this information for automatic adjustment. Sensors that measure the conductivity must be recalibrated for different chemicals.

Some piston and diaphragm pumps are driven by a water motor. As water flows through the injector, it causes a cam to turn and push a piston back and forth. In a diaphragm pump, the piston or cam motion is transmitted to the diaphragm. Consequently, since the revolution of the cam depends on the flow rate of water in the irrigation system, oscillation of the piston and/or diaphragm also varies with water flow rate. In this case the chemical flow is proportional to the flow rate in the irrigation system.

Another way of driving the injector using irrigation water is presented in Figure 5. In this case a mechanism contains two pistons of different size and a series of valves. The larger piston is driven by the pressure in the irrigation system. A smaller piston injects a chemical into the irrigation line.

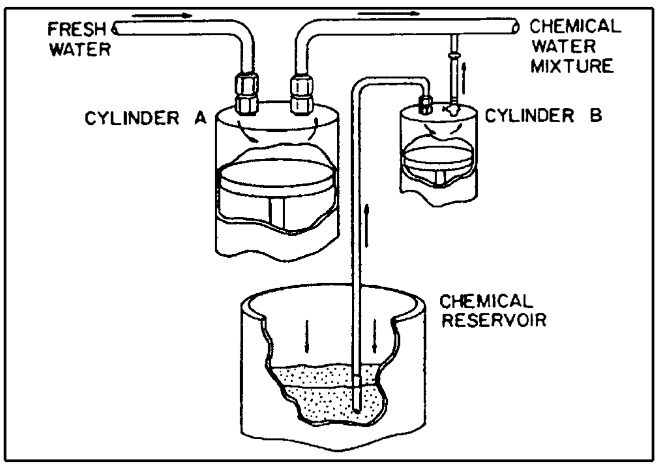

Fig. 5. Water driven piston injector.

Piston and diaphragm pumps inject chemicals in concentrated pulses separated in time. Some pumps are equipped with double acting pistons or diaphragms to minimize variations in the concentration of chemicals in the irrigation system. In these cases the volume on both sides of the piston or the diaphragm is used for pumping chemical (Figure 6). However, if the pipe line length between the injection port and the first point of application is short, a blending tank should follow the injection to ensure adequate mixing of water and fertilizer.

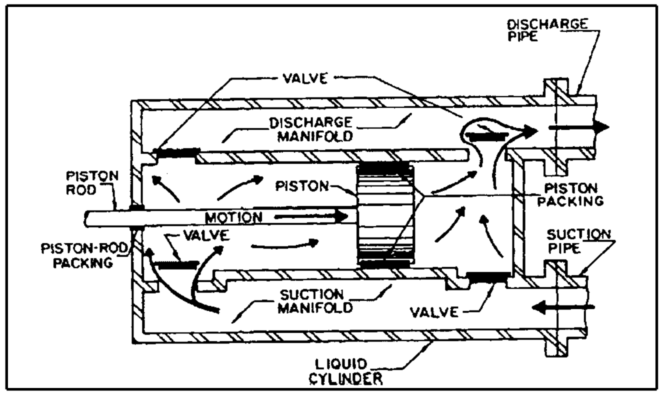

Fig. 6. Double acting piston pump.

ROTARY PUMPS

Rotary pumps transfer chemical from suction to discharge through the action of rotating gears, lobes or other similar mechanisms. Both, gear or lobe types of rotary pumps are sometimes used for chemical injection into irrigation systems. The operation of a gear or lobe pump is based on the partial vacuum which is created by the unmeshing of the rotating gears (Figure 7) or lobes (Figure 8). This vacuum causes the chemical to flow into the pump. Then, it is carried between the gears or lobes and the casing to the discharge side of the pump. Gear and lobe pumps produce approximately constant flow for a given rotor speed, and the injection rate does not change with flow rate in the irrigation system. Flow sensors, described above for reciprocating pumps, can be used to assure a constant injection rate.

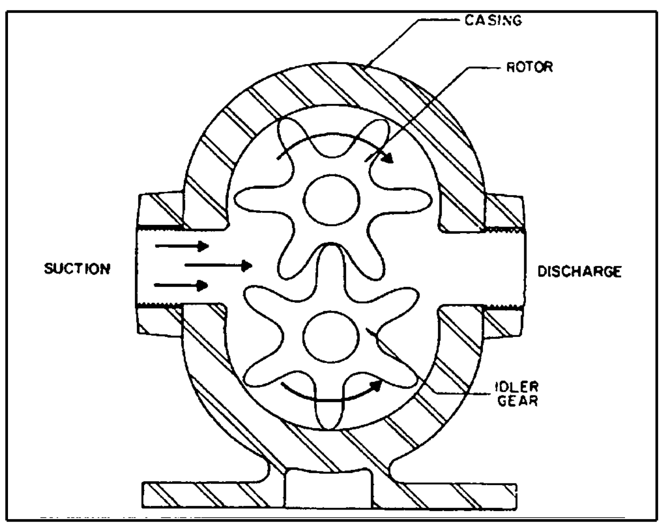

Fig. 7. Gear pump.

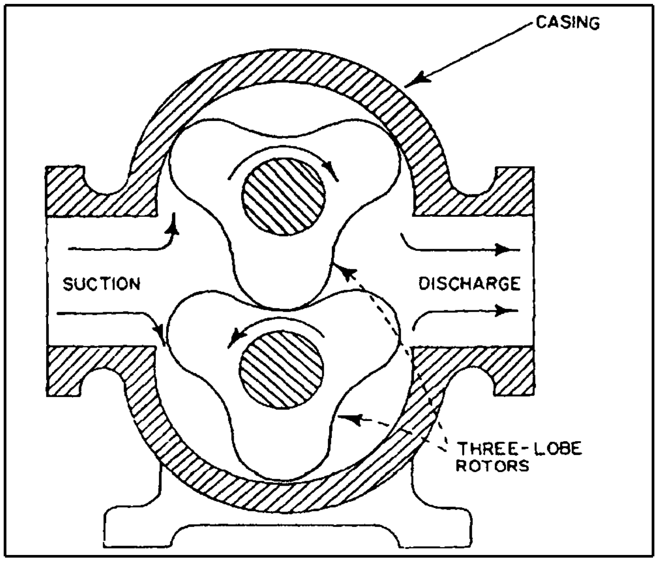

Fig. 8. Lobe pump.

Peristaltic Pumps

Peristaltic pumps are used mostly in chemical laboratories, but they can be used for injection of chemicals into small irrigation systems. Their capacity is limited and most of them produce a pressure of only 30 to 40 psi. A typical peristaltic pump is presented in Figure 9 . A flexible tube is pressed by a set of rollers and an even flow is produced by this squeezing action. The pump is suitable for pumping corrosive chemicals since the pumped liquid is completely isolated from all moving parts of the pump.

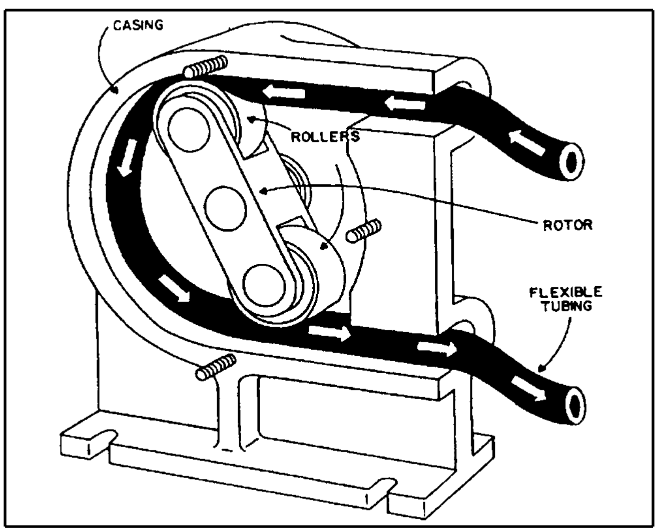

Fig. 9. Peristaltic pump.

PRESSURE DIFFERENTIAL METHODS

The idea of injection using pressure differential is quite simple. Basically, if the pressure at the point of injection is lower than at the point of intake of the chemical, the chemical will flow into the line. There are several injection techniques which use the above principle. They can be separated into two distinctive groups. Injection on the suction side of the irrigation pump and injection on the discharge side of the irrigation pump.

Suction Pipe Injection

The suction pipe injection technique can be used in irrigation systems using centrifugal pumps which are pumping water from the surface source such as a pond, lake, canal or river. In Florida, this method is not permitted for irrigation systems using groundwater supply, and it is approved for injection of fertilizer only (see IFAS Extension Bulletin 217).

The method described above requires only a minimum investment. The equipment necessary for this type of injection is a pipe or a hose, a few fittings and an open container to hold the fertilizer solution (Figure 10). The rate of chemical flow depends of the suction produced by the irrigation pump, the length and size of the suction line, and the level of chemical in the supply tank. This rate can not be easily adjusted.

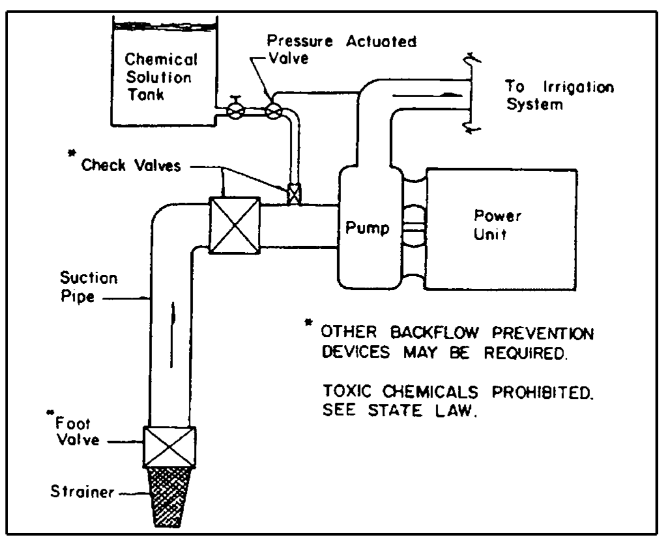

Fig. 10. Suction line injection.

Discharge Line Injection

The differential pressure injection technique can also be used on the discharge side of the pump. This is usually done by redirecting part of the main flow through the chemical tank and providing a pressure drop in the irrigation line between the point where the water is taken and the point where the chemical enters the irrigation line. The pressure drop is accomplished by using some kind of restriction in the line such as a valve, orifice, pressure regulator or other device which would create a pressure drop. The use of valves allows for adjustment of the pressure drop which also allows for some adjustment of the injection rate.

Pressurized Mixing Tanks

A mixing tank injector operates at the discharge line on a pressure differential concept. The water is diverted from the main flow, mixed with fertilizer and injected or drawn back into the main stream of the system (Figure 11). A measured amount of fertilizer required for one injection is placed in the cylinder. The flow back into the main line is often controlled by a metering device installed on the inlet side of the injector. The concentration of the injection changes as the chemical becomes diluted as the water enters the tank during injection. To operate, again, as described previously, there must be a pressure differential in the irrigation line between the inlet and the outlet of the injector.

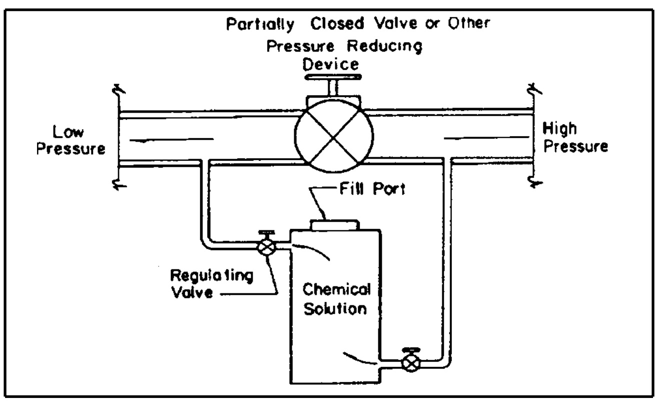

Fig. 11. Pressurized mixing tank.

Proportional Mixers

Proportional mixers are modified pressurized mixing tanks. They operate on the displacement principle. The chemical is placed in a collapsible bag which separates the chemical from the water (Figure 12). The amount of chemical forced into the proportioning valve is replaced with displacement water outside the chemical solution bag. As water enters the tank it displaces chemical and never returns into the system. As long as the pressure and the flow rate in the system do not vary significantly the injection rate will remain constant.

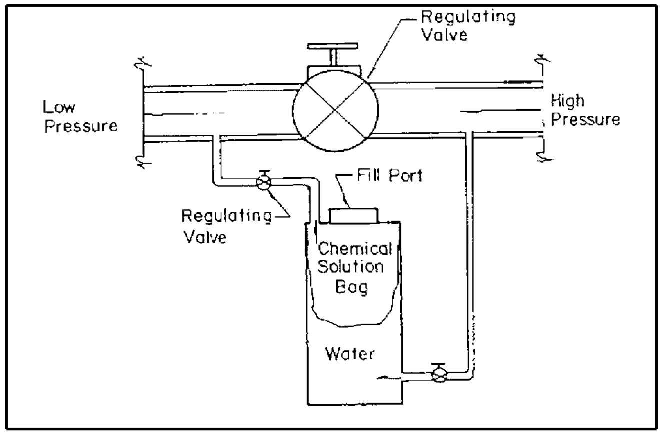

Fig. 12. Proportional mixer.

In irrigation systems where flow fluctuations can be expected, proportioning control valves must be used. If the injector is a true proportional mixer the proportioning valve must respond to the changes of flow not pressure changes in the irrigation system.

VENTURI INJECTOR

Chemicals can be injected into a pressurized pipe using the venturi principle. A venturi injector is a tapered constriction which operates on the principle that a pressure drop accompanies the change in velocity of the water as it passes through the constriction. The pressure drop through a venturi must be sufficient to create a negative pressure (vacuum) as measured relative to atmospheric pressure. Under these conditions the fluid from the tank will flow into the injector (Figure 13). Most venturi injectors require at least a 20% differential pressure to initiate a vacuum. A full vacuum of 28 in of mercury is attained with a differential pressure of 5% or more.

A small venturi can be used to inject small chemical flow rates into a relatively large main line by shunting a portion of the flow through the injector. To assure that the water will flow through the shunt, a

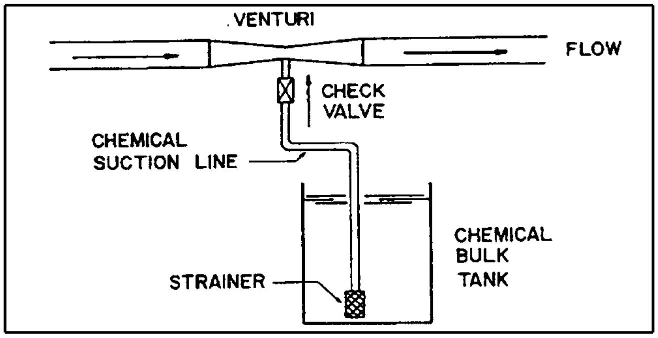

Fig. 13. Venturi injector in the main line.

pressure drop must occur in the main line. For this reason the injector is used around a point of restriction such as valve, orifice, pressure regulator or other device which creates a differential pressure (Figure 14). A centrifugal pump, used to provide additional pressure in the shunt (Figure 15), can also be used.

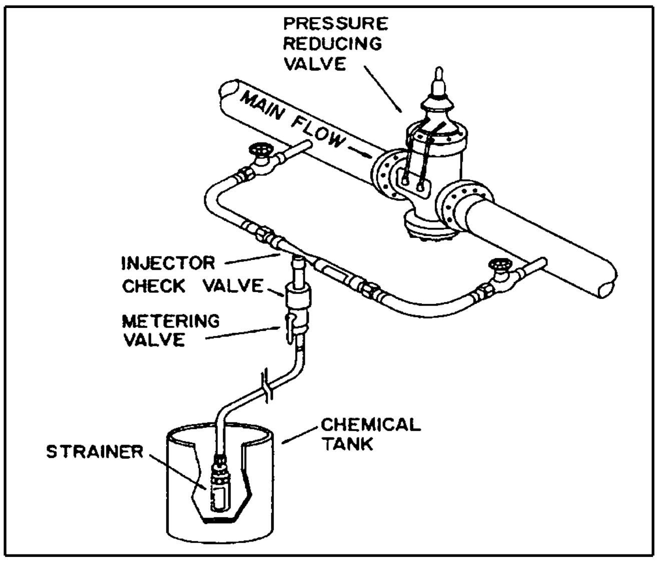

Fig. 14. Small venturi injector with regulator valve for pressure drop in the main line.

A venturi injector does not require external power to operate. It does not have any moving parts, which increases its life and decreases probability of failure. The injector is usually constructed of plastic and it is resistant to most chemicals. It requires minimal operator attention and maintenance. Since the device is very simple, its cost is low as compared to other equipment of similar function and capability. It is easy to adopt to most of new or existing systems providing that there is sufficient pressure in the system to create the required pressure differential.

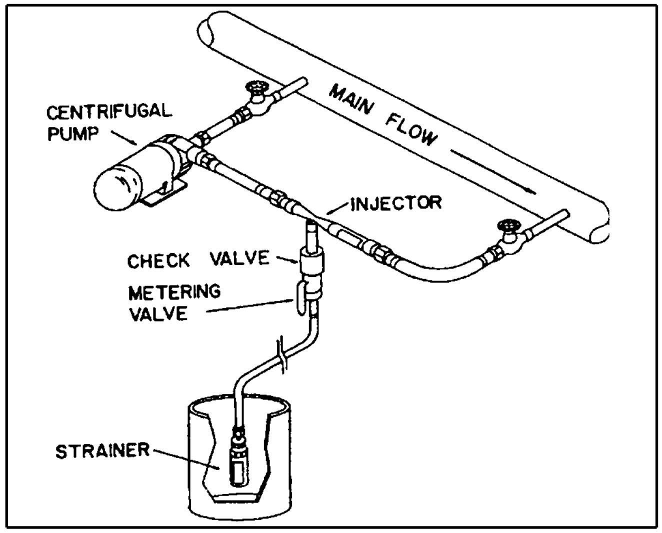

Fig. 15. Small venturi injector in cojunction with a centrfugal booster pump.

Venturi injectors come in various sizes and can be operated under different pressure conditions. Suction capacity (injection rate), head loss required, and working pressure range will depend on the model. It is important to realized that the suction capacity depends on the liquid level in the supply tank. As the liquid level drops, the suction head increases resulting in the decreased injection rate. To avoid this problem some manufacturers provide an additional small tank on the side of the supply tank, where the float valve maintains the fluid level relatively constant. The fluid is injected from this additional tank.

COMBINATION METHODS

There are some injectors on the market which employ combination of the different principles of injection at the same time. The most common combination is a pressure differential combined with a venturi meter or some measuring device which operates on the venturi principle.

Direct use of pressure differential in combination with a venturi can be found in some systems where the pressure drop required for a venturi may be difficult to provide due to design restrictions of the existing irrigation system. The combination of a venturi device with a pressurized chemical tank may be used in this case (Figure 16). The chemicals are placed in the tank. Since the water flowing through the tank is under pressure, a sealed airtight pressure supply tank which is constructed to withstand the maximum operating pressure is required. In this case the injection rate will change gradually due to the change of chemical concentration in the tank as the water enters the tank during injection.

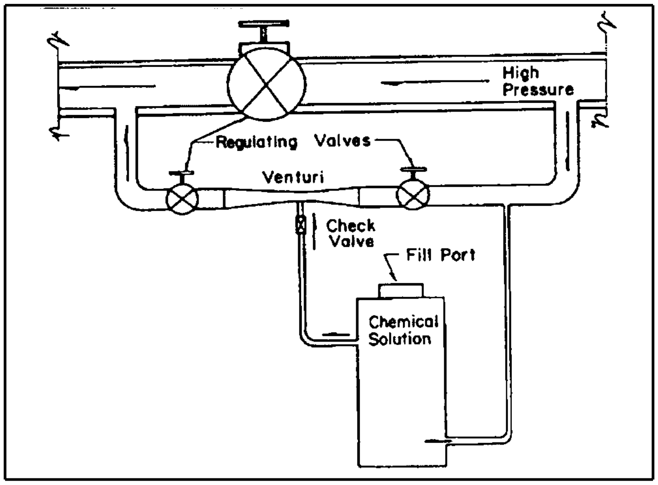

Fig. 16. Combination of a pressurized tank and venturi injector.

Various metering valves which are used with mixing and proportioning tanks operate on pressure or flow changes in the irrigation system. There are many designs of these valves. Frequently it is some application of the venturi meter or the orifice with changing diameter. The manufacture should be contacted for descriptions and operation instructions for various metering and proportioning valves.

BACKFLOW PREVENTION LAW

Before injecting any chemicals into an irrigation system it is necessary to check that the system is provided with the required backflow prevention system for a given type of chemical. The general rules for backflow prevention in Florida are presented in IFAS Extension Bulletins 217 and 248. In addition local ordinances should be checked since they may be more restrictive.

Chemical injection on the suction side of a centrifugal pump is generally not permitted in Florida. The exception is a system which is using a surface water supply and only fertilizers are being injected into the system. Florida backflow prevention law requires that a double protection of a check valve and a foot valve will be used upstream of injection port in this case.

According to Environmental Protection Agency (EPA) only piston and diaphragm injection pumps can be used for pesticides and other toxic chemicals. Other methods described in this publication can be used for injection of fertilizers or cleaning agents, such as chlorine or acids.

SUMMARY

Different types of injectors are discussed in this publication. These injectors are classified into five basic groups depending on their principles of operation. Basic principles of operation, advantages and disadvantages are presented.

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Table 1.

Table 1. Comparison of various chemical injection methods

Pump/Method	Injector	Advantages	Disadvantages
Centrifugal Pumps	Centrifugal Pump Injector	Low cost. Can be adjusted while running.	Calibration depends on system pressure.
Positive Displacement Pumps - Reciprocating Pumps	Piston Pumps	High precision. Linear calibration. Very high pressure. Calibration independent of pressure.	High cost. May need to stop to adjust calibration. Chemical flow not continuous.
	Diaphragm Pumps	Adjust calibration while injecting. High chemical resistance.	Non-linear calibration. Calibration depends on system pressure. Medium to high cost. Chemical flow not continuous.
	Piston/Diaphragm	High precision. Linear calibration. High chemical resistance. Very high pressure. Calibration independent of pressure.	High cost. May need to stop to adjust calibration.
Positive Displacement Pumps - Rotary Pumps	Gear Pumps, Lobe Pumps	Injection rate can be adjusted when running.	Fluid pumped cannot be abrasive. Injection rate is dependent on system pressure. Continuity of chemical flow depends on number of lobes in a lobe pump.
Positive Displacement Pumps - Misc. Pumps	Peristaltic Pumps	High chemical resistance. Major adjustment can be done by changing tubing size. Injection rate can be adjusted when running.	Short tube life expectancy. Injection rate dependent on system pressure. Low to medium injection pressure.
Pressure Differential Methods	Suction Line Port	Very low cost. Injection rate can be adjusted while running.	Permitted only for surface water source and injection of fertilizer. Injection rate depends on main pump operation.
Pressure Differential Methods - Discharge Line	Proportional Mixers	Low to medium cost. Calibrate while operating. Injection rates accurately controlled.	Pressure differential required. Volume to be injected is limited by the size of the injector. Frequent refills required.
	Pressurized Mixing Tanks	Medium cost. Easy operation. Total chemical volume accurately controlled.	Pressure differential required. Variable chemical concentration. Cannot be calibrated for constant injection rate.
Venturi Injectors	Venturi	Low Cost. Water powered. Simple to use. Calibrate while operating. No moving parts.	Pressure drop created in the system. Calibration depends on chemical level in the tank.
Combination Methods	Proportional Mixers/Venturi	Greater precision than proportional mixer or venturi alone.	Higher cost than proportional mixer or venturi alone.