Chemigation

Guidelines for British Columbia

Irrigation Industry Association
of
British Columbia

Province of British Columbia
Ministry of Agriculture, Fisheries and Food
SOILS AND ENGINEERING BRANCH

CHEMIGATION

GUIDELINES FOR BRITISH COLUMBIA

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TABLE OF CONTENTS

1.	Introduction		1-1
2.	Laws and Regulations Affecting Chemigation		
	2.1	Federal Legislation	2-1
	2.2	Provincial Legislation	2-1
	2.3	Codes and Bylaws	2-3
	2.4	Standards	2-4
3.	Chemigation Considerations		
	3.1	Advantages	3-1
	3.2	Disadvantages	3-3
	3.3	Irrigation System Design Considerations	3-4
	3.4	Irrigation System Operation Considerations	3-7
4.	Cross Connection Control		
	4.1	Why is Chemigation a Potential Hazard	4-1
	4.2	Backflow Prevention Device Selection	4-2
	4.3	Guidelines for Pesticide, Herbicide and Insecticide Application	4-8
	4.4	Injection System Requirements	4-9
	4.5	Backflow Prevention Requirements	4-10
	4.6	Additional Precautions	4-12
5.	Chemical Selection		
	5.1	Selection Criteria	5-1
	5.2	Fertilizers	5-1
	5.3	Herbicides	5-9
	5.4	Pesticides	5-10
6.	Injection Equipment		
	6.1	Injector Selection	6-1
	6.2	Passive Injectors	6-2
	6.3	Active Injectors	6-6
	6.4	Injector Calibration	6-10
7.	Calculating Injection Rates		
	7.1	Determining a Method of Calculating Injection Rates	7-1
	7.2	Calibrating an Injection Pumping System	7-2
	7.3	Batch Chemigation Examples	7-3
	7.4	Continuous Move Chemigation Examples	7-10
Appendix A		Sample Chemigation Bylaw	A-1
Glossary			
Bibliography			

LIST OF FIGURES

Figure 3.1	Solute Dispersal Along Irrigation System	3-8
Figure 4.1	Double Check Valve Assembly	4-4
Figure 4.2	Reduced Pressure Backflow Prevention Principle Device	4-6
Figure 4.3	DCVA or RPBD Installation - Above Ground	4-7
Figure 4.4	DCVA or RPBD Installation - Below Ground	4-7
Figure 4.5	Injector System Arrangement	4-9
Figure 6.1	Pitot Tube Injector	6-3
Figure 6.2	Pressure Differential Injection System	6-4
Figure 6.3	Venturi Injection System	6-5
Figure 6.4	Metering Injection Pump	6-8
Figure 6.5	Water Turbine Driven Injector	6-9
Figure 6.6	Piston Drive Injection System	6-10

LIST OF TABLES

Table 3.1	Irrigation System Uniformities	3-6
Table 3.2	Hand Feel Moisture Test	3-10
Table 3.3	Depth of Water Penetration (inches) per Inch of Water Applied	3-10
Table 5.1	Granular Fertilizer Properties	5-3
Table 5.2	Fertilizer Solutions	5-5
Table 5.3	Typical Grades of Clear Liquid Mixes and Suspension	5-6
Table 5.4	Inorganic Sources of Micronutrients	5-8
Table 6.1	Venturi Injector Selection	6-6

1 Introduction

Chemigation is the term used to define the practice of applying chemicals to a crop through an irrigation system. In agriculture the types of chemicals applied are generally fertilizers to promote crop production and plant growth. Commodities such as tree fruits, vegetables, small fruits and berries, greenhouse and nursery use trickle irrigation systems to apply fertilizers directly to the plant roots. In drier climates such as the Okanagan the utilization of fertigation techniques is the only viable method of applying fertilizers to crops using trickle irrigation systems. Insufficient rainfall will not ensure incorporation of broadcast fertilizers into the soil under a trickle irrigation regime in these drier climates.

The use of trickle irrigation systems and fertigation will continue to increase due to the many advantages offered by this technology. Better application efficiencies offer a reduction in the amount of fertilizer used, timely application of fertilizers and less impact on the environment.

The term chemigation also applies to the application of herbicides, insecticides, fungicides, nematocides and growth regulators through sprinkler and trickle irrigation systems. While these types of chemicals are currently not applied extensively in British Columbia, some are in other irrigated regions of the world.

The application of fertilizers imposes minimal health concerns and risks to water purveyors. However the potential to apply other chemicals is seen as a greater risk. Potential contamination of the water source due to backsiphonage and backpressure are possible if an unexpected shutdown of the irrigation system should occur while injection is taking place. This risk can be minimized if proper backflow prevention devices are installed and inspected and if good chemigation practices are followed.

The intent of this publication is to inform the agriculture industry and water purveyors of the laws, regulations and standards that currently exist in British Columbia. The manual provides information on the design and operation of chemigation systems. Guidance on the selection of chemicals and methods of calculating chemical injection rates are also given.

Irrigation districts with cross connection control bylaws refer to this manual as an operation and procedure manual for chemigation. Producers taking water from streams or other natural water sources are often not under the authority of a water purveyor and their cross connection bylaws. **Section 4 of this manual should be used by agricultural producers as a chemigation and cross connection control standard where a water authority has not established a cross connection control bylaw.**

2 Laws and Regulations Affecting Chemigation

There are many provincial, federal and municipal laws, regulations and codes that may pertain to the use, handling and application of chemicals through irrigation systems. To ensure compliance, knowledge of existing legislation and the jurisdiction of each level of government is required.

2.1 FEDERAL LEGISLATION

Pest Control Products Act

The Federal Pest Control Products (PCP) Act says every pesticide must be registered by Agriculture Canada before it can be sold in Canada. Registered products require labels to include a PCP number and a listing of crops and pests on which the pesticide can be applied. The PCP Act also defines the method by which pesticides may be applied. **Dispensers must not sell and applicators must not use pesticides for purposes other than those described on the label unless authorization from provincial authorities is obtained.** Injection of a pesticide into an irrigation system is allowed only if this method of application is specified on the label. It is illegal to import a pesticide unless it is registered in Canada and an import permit is obtained.

Food and Drugs Act

The Food and Drugs Act says how much pesticide residue can be on crops at harvest. The Health Protection Branch checks pesticide residues on crops and may seize a crop if the levels are too high. Avoid high residue levels by following label directions.

Fisheries Act and Migratory Birds Regulations

A pesticide user can be charged if found responsible for killing or injuring fish or migratory birds with a pesticide. It is also an offense to contaminate waters used by fish or migratory birds.

2.2 PROVINCIAL LEGISLATION

Pesticide Control Act And Regulations

The Pesticide Control Act and Regulations regulate the sale and usage of pesticides in B.C. Use includes the storage, transportation, handling and application of pesticides.

These laws say:

- application cannot cause an unreasonable adverse effect;
- substances must be classified as pesticides and designating restricted use pesticides;
- how a pesticide must be contained, transported, stored, prepared, mixed, applied or sold;
- how a pesticide and the equipment or container used to store, prepare, mix or apply the pesticide must be disposed of;
- what type of record must be maintained by persons who store, prepare, mix, apply, transport, sell or dispose of a pesticide;
- what standards of competence and requirements are necessary for a person to obtain a licence, permit or certificate;
- that persons and a body of water or land area are exempt from this Act when application may be unnecessarily restrictive.

Workers Compensation Act and Regulations

The Workers Compensation Act and Regulations govern the use of pesticides at worksites that come under the authority of the Workers' Compensation Board.

These regulations state:

- Health and Safety information on pesticides
- Safe use of application equipment and pesticides
- Control of worker exposure to chemicals
- Personal protective equipment selection and use

Waste Management Act

The Waste Management Act says that wastes cannot be put into the environment without a permit or approval or compliance with regulations. The Agriculture Waste Control Regulation allows any agricultural operation following the Code of Agricultural Practice to be exempt from having to obtain a permit under the Waste Management Act for the use and handling of agricultural waste.

The Code allows the discharge of plant and animal waste emanating from traditional farming operations that are managed and applied as organic fertilizers to promote crop production to be exempt from the Waste Management Act. The Code of Practice outlines practices for using and storing agricultural wastes in an environmentally sound manner.

The intent of this publication is to provide information on the application of chemicals through an irrigation system according to the Code of Agricultural Practice.

Health Act

The Safe Drinking Water Regulation under the Health Act sets minimum standards for testing and bacteriological water quality. The regulation gives medical health officers the authority to require water purveyors to provide safe drinking water. While chemical standards are not set under this regulation at this time, these standards can be adopted, as they are deemed necessary.

Water Act

The Province of British Columbia owns all water and permits the use of it only by licence under the Water Act. A Water Licence is a legal document issued by the Comptroller of Water Rights that specifies the conditions governing the right to the use of water. A water licence must be obtained before taking any water from a surface water source. The need for protection of British Columbia's water supplies is mandated under the Ministry of Environment's water management program.

2.3 CODES AND BYLAWS

B.C. Plumbing Code

The B.C. Plumbing Code sets minimum requirements for wastewater and storm water drainage systems from buildings to the point of connection with public services. Water purveyors may set more stringent standards but cannot set standards that are less rigorous than what is outlined in the B.C. Plumbing Code.

Section 6.2 of the Plumbing Code provides information on protection from contamination from cross connection systems. These standards are addressed in Section 4, Cross Connection Control, of this manual.

Code of Agricultural Practice for Waste Management

The Code of Agricultural Practice for Waste Management describes environmentally sound practices for using, storing and handling agricultural wastes and products. This code is referenced in a regulation under the Waste Management Act.

This manual is referenced in the Commodity Environmental Guidelines produced to support the Code of Agricultural Practice.

Municipal Bylaws

Municipalities, Irrigation Districts and other water purveyors may make bylaws governing the application of chemicals through irrigation systems. Many water purveyors will have adopted a bylaw similar to the example shown in Appendix A. Contact your water purveyor to obtain a copy of the bylaw that pertains in your area.

Many bylaws may specify which type of backflow prevention device must be used. Backflow prevention devices should be tested upon installation and once every year after that. The device must be tested by a certified tester who is familiar with the design and intended operation of the device.

2.4 STANDARDS

Canadian Standards Association (CSA)

The Canadian Standards Association has developed standards (CAN/CSA-B64-M88) for materials, design and construction, repairs, test requirements and test methods for backflow preventers and vacuum breakers. Backflow prevention equipment in British Columbia must meet this standard.

American Water Works Association (AWWA)

The American Water Works Association, Pacific Northwest Section publication entitled "Acceptable Procedure and Practice in Cross Connection Control Manual" is considered the industry standard in British Columbia. The manual covers the selection of backflow prevention devices, installation practices, requirements for equipment approval and testing, test procedures and maintenance.

Mechanical devices approved for acceptable backflow prevention have been reviewed for adequacy of design and tested for mechanical and hydraulic reliability. The University of Southern California Foundation of Cross Connection Control and Hydraulic Research is recognized as a reputable organization to carry out this testing. Provinces and municipalities have lists of devices that are approved for backflow prevention by USC and CSA.

American Society of Agricultural Engineers

The ASAE Engineering Practice standard EP409.1 "Safety Devices for Chemigation" outlines backflow prevention systems for injection devices on pumping systems. Standards on interlocks between the irrigation pumping system and the chemigation device are outlined. Sections of this standard that pertain to B.C. conditions are presented in Section 4, Cross Connection Control.

3 Chemigation Considerations

The goal of a chemigation system is to apply the proper amount of chemical to the target area in a safe, efficient and uniform manner. The following precautions must be taken to achieve this goal:

- assure personal protection
- be aware of the danger to the environment
- calibrate the injection equipment
- apply the correct amount of chemical at the right time
- apply the chemical at the correct concentration
- use a well designed and maintained irrigation system

Subsequent sections in this manual will explain how the above precautions can be met. Keep in mind that the chemical cannot be distributed more evenly than the water is applied by the irrigation equipment.

3.1 ADVANTAGES

The application of chemicals through an irrigation system offers many advantages to the farmer. Advantages obtained depend on the type of irrigation system used and type of chemical being applied.

Sprinkler System Advantages

- **Reduce cost of chemical application.** With chemicals such as herbicides, application through an irrigation system may save 50 percent of the application costs.

- **Reduces energy consumption. Energy** consumption by chemigation application methods compared to conventional methods may be reduced by up to 90%.

- **Insures timely application of chemicals.** Fertilizers and other chemicals can be applied to the crop at the most opportune time, even if the field is not trafficable by farm implements. Nutrients can easily be applied to the crop throughout the growing season at specified rates and intervals.

- **Improves application uniformity. Irrigation** systems that are properly designed and operated can apply chemicals more uniformly than aircraft and can be as uniform as ground sprayers.

- **Reduces chemical use.** Studies **have** shown that less fertilizer is required when nutrients are applied more efficiently, more often and when required by the crop. The same applies to herbicides and pesticides. The potential for chemicals to be leached into groundwater is therefore reduced.

- **Reduces labour costs.** One operator can apply chemicals easily and efficiently to large acreages.

- **Reduces machinery equipment needs.** Chemigation saves wear on tractors and sprayers.

- **Reduces soil compaction.** Soil conditions are improved and mechanical damage to the crop is reduced as there is less **movement** of vehicles over the field.

- **Improves operator safety. Since** the operator does not have to be in the target area, exposure of the operator to herbicides, pesticides and insecticides applied through an irrigation system is greatly reduced.

- **Improves crop production.** Chemigation systems may simplify cultural practices and improve crop production and quality if used correctly. Timely fertilizer applications can significantly increase crop yields.

Trickle System Advantages

Trickle irrigation systems offer additional benefits to sprinkler systems in applying nutrients and systemic pesticides. As water is applied directly to the plant's root zone, nutrients can be efficiently applied. Trickle systems may not be compatible with herbicides or insecticides as the chemical is not applied evenly over the entire ground surface. An exception would be spray emitter systems which could be used for weed control on some crops. The following are advantages of trickle irrigation systems:

- **Ensures incorporation in drier climates.** Fertigation is the only method of ensuring that fertilizers are incorporated into the soil when trickle systems are used to irrigate crops in arid regions such as the interior of British **Columbia**. Fertigation is therefore a necessity instead of an option for agricultural practices in these regions.

- **Ensures efficient application due to higher application efficiencies.** Since trickle irrigation systems apply water directly to the plant's root system, better uniformity of fertilizer application to the crop can be attained.

- **Increases fertilizer availability to the crop.** Fertilizers are applied in a form by which they can be easily taken up by the plant.

- **Allows for modification of fertilizer application for crop maturity.** Nutrients can be applied throughout the growing **season** with precalculated amounts and frequencies to meet crop demand at various growing stages.

- **Injection systems are required for maintenance of the trickle system.** The addition of chlorine and acids to a trickle **system** is required to prevent algae and precipitate buildup in the emitters and lateral lines. The same injection equipment may be used for chemigation.

3.2 DISADVANTAGES

Disadvantages of chemigation include but may not be limited to the following considerations.

- **Chemigation is not viable for all chemicals.** Not all chemicals are soluble enough to be applied as a solution and some chemicals may not act as intended under an irrigation application regime. More than one method of chemical application must therefore be retained.

- **Specified use and application according to product label.** A herbicide, pesticide or insecticide may only be applied to a field or crop in British Columbia as described on the product label. Application through an **irrigation** system must be specified on the label.

- **Requires the addition of safety equipment.** To prevent the possibility of backpressure or backsiphonage into a potable water source, approved cross connection control equipment must be installed and proper procedures followed.

- **Requires a change in management techniques.** Personnel in charge of the chemical application must fully understand the calibration of injection equipment and the operation of the injector, irrigation system, check valves and backflow prevention equipment.

- **Portability of equipment.** If a farmer has more than one field, duplication of equipment will be required unless the injection system, solution tank and safety equipment are connected as one unit and can easily be transported from field to field.

- **Timing of application may be limited due to weather.** Sprinkler irrigation systems are susceptible to drift in windy **conditions** that will affect uniformity and effectiveness of the application. Applications should therefore be limited to good weather conditions.

- **Unwanted chemical residue.** Sprinkler systems **may** leave a residue of the chemical on the crop.

- **Corrosivity of chemical to irrigation system components**. Chemical solutions may be corrosive to irrigation equipment.

- **Unnecessary irrigation.** Using an irrigation **system** to apply chemicals may apply moisture to the crop at a time when it is not required or when the soil is already too wet.

- **Increasing soil acidity.** The injection of **some** types of fertilizers into an irrigation system may increase the acidity of the soil. This is especially true for trickle irrigation systems, which concentrate the fertilizer application to a small area.

- **Management Requirements.** The **operator** must recognize that safe and effective chemigation requires careful and attentive management.

3.3 IRRIGATION SYSTEM DESIGN CONSIDERATIONS

Many irrigation system design factors must be considered for chemigation if good application uniformity is to be obtained. While there are many operation characteristics that need to be understood as well, it is virtually impossible to achieve good uniformity if the irrigation system is not designed correctly in the first place. System operation is discussed in the next section. This section provides minimum criteria for the design of irrigation systems to be used for chemigation.

Irrigation System Location

Proximity of the irrigation system to dwellings, surface water sources such as ditches, streams and lakes, neighbouring crops, roadways, playgrounds and residential areas must be carefully considered. The safety of people, wildlife, domestic animals and other non target areas must be considered.

Crop Type

Selection of an irrigation system is often determined by the type of crop to be irrigated.

Trickle irrigation systems are often used for tree fruits, grapes, strawberries and other horticultural crops because of water application efficiency and the ability to control fertilizer application directly to the plant's roots. High density orchard plantings require quick tree response after planting and early fruit development to realize a return on capital investment. It is imperative that plantings use fertigation to apply plant nutrient requirements. The injection of herbicides and pesticides through a trickle system is generally not effective.

Cranberries and forage crops are best suited for sprinkler irrigation systems. Overhead and undertree sprinkler systems are also popular on orchards and vineyards for a variety of reasons. Overhead sprinkler systems used for irrigation, frost protection or crop cooling purposes on tree fruits or cranberries can be adapted to chemigation. (A minimum application uniformity of 85% should be achieved.) However the coefficient of uniformity for most overhead systems designed for these purposes are not adequate for chemigation.

For high value crops, more than one type of irrigation system will be required to accomplish all tasks.

Soil Type

The maximum infiltration rate of water into the soil and available water storage capacity of the soil differ with soil type. Soil types can vary significantly over an entire field requiring a change in the operation of the irrigation system. Coarse textured soils can have high infiltration rates but can store very little water within the plant's root zone. Conversely, fine textured soils can store large amounts of water but have low infiltration rate capabilities. High application rates on fine textured soils increase runoff potential, while excessive amounts of irrigation on coarse textured soils increase the potential for leaching of chemicals below the crop root zone and into groundwater.

Chemigation systems must be operated within the limits of the soil types present to reduce the potential for runoff and for leaching.

An understanding of soil water holding capacity is also important to ensure that the chemical added is moved into the soil to an appropriate depth with respect to the plant rooting volume. Section 3.4 provides further information on calculating the depth of chemical penetration into the soil.

Topography

Field topography can cause pressure differences along an irrigation lateral, which affect application uniformities. Low pressure center pivot and trickle systems are most susceptible to pressure differences caused by elevation or friction loss. Sprinkler irrigation systems can also be affected if the elevation changes are in excess of 5 m or more.

For chemigation systems, varying the nozzle size along a lateral to accommodate pressure fluctuations is not an acceptable method of rectifying this problem. Pressure or flow regulators on each individual sprinkler head are required to ensure uniform discharge for each sprinkler along the lateral. Pressure compensating emitters are recommended to maintain system uniformity for trickle systems.

Drift and Runoff Potential

Drift and runoff are the two leading causes of chemical losses from chemigation systems. Environmental conditions during application, sprinkler types, type of chemical being applied and climatic conditions after application all affect the magnitude of chemical losses.

Water discharged from a sprinkler nozzle under pressure emerges as a fine spray. Part of the spray is evaporated within the wetted area, intercepted by vegetation and soil or carried away by wind outside the intended target area. Wind drift can be a potentially hazardous situation. Chemigation should not be carried out if wind conditions are strong enough to cause significant drifting to non target areas.

Runoff depends not only on the irrigation system application rate and soil infiltration rate but is also influenced by factors such as field slope, surface vegetation, crop cover and soil surface residue. Irrigation systems applying chemicals must be designed and operated to prevent any runoff from occurring.

Irrigation System Characteristics

The physical characteristics of the irrigation system will determine the type of injection system, selection of chemicals that can be applied, application rate and duration of application. Irrigation systems can be divided into two categories, **stationary and continuous move** systems.

Stationary systems include handlines, wheel moves, solid set sprinklers, trickle and microsprinkler systems. These types of systems irrigate a block of land at a constant application rate over time. A batch of chemicals can therefore be mixed and applied during the irrigation interval. The duration of application will be determined by the type of chemical being applied. Some chemicals must be incorporated to be effective, requiring application of enough water to move the chemical into the soil. Other chemicals such as nitrate nitrogen are very mobile and should be left near the soil surface to avoid potential groundwater problems. Chemicals intended for foliar applications should only be applied by overhead sprinkler systems during the end of an irrigation set with a minimum amount of flushing.

Continuous move systems include center pivots, travelling guns, and overhead boom systems used in nursery and greenhouse operations. These types of systems irrigate a block of land with a predetermined amount of water but at varying application rates. (The application rate at the pivot point is much less than at the last pivot tower.) The rate of chemical injection must therefore be matched with the rate of travel. Batch application of chemicals cannot be used with this type of irrigation system.

Irrigation systems used for chemigation must be in good working order and managed in an environmentally sensitive manner. **All chemigation systems must have appropriate safety equipment installed to prevent backflow to potable water supplies.**

Table 3.1 shows the differences in application uniformities between different types of systems.

Table 3.1 Irrigation System Uniformities

Irrigation Method	Uniformity
Wheel move	Fair
Handline	Fair
Solid Set Overtree	Fair
Solid Set Undertree	Poor
Center Pivot	Good
Solid Set Gun	Poor
Travelling Gun	Poor
Trickle	Good

The following system design parameters must be considered in the design of chemigation systems.

Sprinkler Systems

To ensure maximum uniformity, sprinkler irrigation systems used to apply chemicals must be designed and operated to achieve a minimum coefficient of uniformity of 80% and preferably 90%. Even for uniformities of 90% there can still be a 3 - 1 ratio between individual field measurements in the depth of water applied. Further information on determining the coefficient of uniformity can be found in the ***B.C. Sprinkler Irrigation Manual***. A coefficient of uniformity of 80% can only be obtained by designing sprinkler systems to the following minimum standards. The following standards should apply for chemigation systems:

1. The maximum pressure variation along the lateral must not exceed 20% of the sprinkler operating pressure. Flow control nozzles must be used if pressure fluctuations exceed the 20% allowance. Another option is to use pressure regulators at sprinkler heads operating at pressures exceeding the normal operating range.

2. The sprinkler spacing along the lateral should not exceed 50% of the wetted diameter. The spacing between laterals should not exceed 60% of the sprinkler wetted diameter.

3. The sprinkler is operated within the manufacturer's recommended pressure range that is sufficient to provide adequate stream breakup for proper dispersal.

4. The sprinkler head must rotate a minimum of two times per minute.

5. Sprinkler irrigation systems must be operated for at least 15 minutes to achieve uniform application. A 30 minute injection time would attain better uniformity but may be too long for some chemicals.

Trickle

Trickle irrigation systems generally have a coefficient of uniformity exceeding 80% providing the system has been designed correctly. Trickle systems operate at efficiencies in the 85 - 90% range compared to sprinkler systems that are only 65 - 75% efficient. These systems are therefore much superior in the application of fertilizers and systemics than sprinkler systems. However, trickle systems are limited in their ability to apply herbicides and insecticides.

The following factors need to be considered in the design of a trickle system used for chemigation.

1. Emitters should be spaced to effectively irrigate as much of the plant's root volume as possible.

2. An appropriate emitter should be selected for the terrain, crop type and water quality being used. Emitter flow characteristics and product durability for the conditions should be considered. An emitter with a manufacturer's variance coefficient of less than 0.05 should be selected. Emitter flow rates at the beginning and end of the zone should be tested to confirm that discharge rates are within acceptable limits.

3. Emitter operating pressure range should be kept within +/- 10% of the emitter operating pressure. If the trickle system is operating on a slope pressure compensating, emitters should be used.

4. The injection system must be located before the filtration system so that any precipitates that may form will have an opportunity to be filtered out before entering the irrigation system.

3.4 IRRIGATION SYSTEM OPERATION CONSIDERATIONS

To operate a successful chemigation program, the most difficult obstacle that must be overcome by the operator is to ensure good application uniformity. As indicated in the previous section the irrigation system must be designed to distribute the water as uniformly as possible to achieve uniform application of chemicals.

Physical characteristics of irrigation systems which effect the uniformity of chemical injection include the following:

- Solute dispersion occurs as the chemical travels along the irrigation pipeline. The friction affect of the pipe walls on the fluid motion causes this dispersion. A slug of chemical injected into an irrigation system becomes diffuse as the chemical travels along with the irrigation water. See Figure 3.1.

- The irrigation mainline contains a significant amount of water. The travel time for the chemical to reach the discharge point and the time required to flush the system must be considered.

- The operating flow rate for each zone will be different.

- For stationary systems, uniformity of application generally increases with the length of set time. Chemicals that require a short application duration may be difficult to apply uniformly.

- For continuously moving irrigation systems such as center pivots the amount of chemical that can be applied is dependent on the travel speed and concentration of the chemical solution. The available chemical solution may dictate the irrigation travel speed. Check to ensure that the speed chosen will provide good application uniformity.

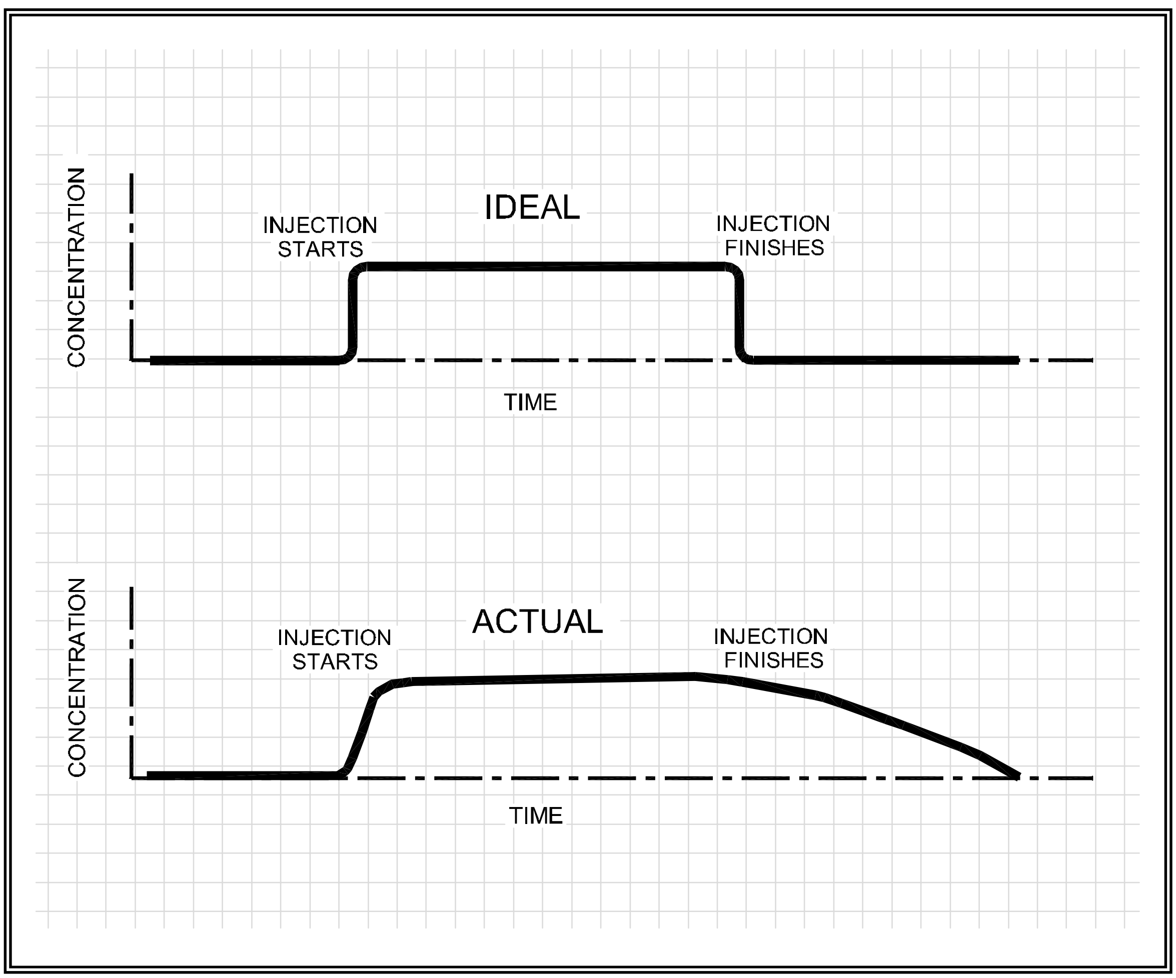

Figure 3.1 **Solute Dispersion Along Irrigation System**

Irrigation system layout and the travel time of chemicals through the system must be known to ensure good application uniformity and adequate flush times for the laterals on chemigation completion.

The following procedures should be used as guidelines in the operation of chemigation systems.

1. Prepare a worksheet showing zones, flow rate per zone, area covered or plants per zone, injection rate and injection time. This is useful for future reference.

2. The irrigation lines should be completely filled and pressurized before starting chemigation.

3. Solid set sprinkler systems should preferably be operated for 1 hour to achieve good application uniformity. This may not be possible for all chemigation applications, but the minimum application duration suggested is 15 minutes.

4. The system should be flushed after chemigation has been completed. The irrigation system must be operated long enough to clear all lines of the chemical being applied. If the irrigation system is shut down before all the chemicals have exited the lateral lines, extra chemical will be applied at low spots where water drains through emitters or sprinklers. Chemical that was intended for the end of the lines will then not reach the target area. A flushing time of 30 minutes should be sufficient for most systems although systems with lengthy and large mainlines may require longer durations for system flushing.

   A dye test should be conducted to determine the length of time required for the last of the chemical to exit the final sprinkler or emitter. The amount of flush time can be reduced by injecting the chemical at the zone control.

5. Mixing a solution separately for each zone reduces the likelihood of error during the application process and allows for proper flushing of the irrigation system to increase application uniformity. If a controller with the capability of programming injections during scheduled irrigations is used, a large batch tank of chemical can be mixed for all zones. The amount of chemical applied to each zone will then be controlled by adjusting injection times.

6. When applying chemicals that may damage the crop foliage, the sprinkler irrigation chemigation system should be operated for at least one hour after chemical injection has ceased.

7. Post injection treatments may be required to prevent the accumulation of algaes, slimes or precipitates that may plug trickle irrigation systems. High carbonate and/or iron concentrations in some irrigation waters may react with fertilizers and cause insoluble calcium or iron compounds. Certain bacteria can also fix iron as a by-product of metabolism and produce slime or jelly like material inside the trickle irrigation lines. Algae growth may also be enhanced by the addition of nutrients in the water. Special maintenance procedures such as chlorination, adding algaecides, bactericides and pre-treating water with chelating agents may be required when performing fertigation with a trickle irrigation system.

8. The acidity of the soil should be monitored, especially when applying ammonium fertilizers through a trickle irrigation system. Acidity will be dependent on the buffering capacity of the soil. Selection of an appropriate fertilizer source will reduce acidity problems (See chapter 5). Treatment with lime may also be an alternative.

Determining Depth of Chemical Application

The amount of water applied by the irrigation system must be stored within the plant's root zone. Any moisture that is applied that exceeds the holding capacity of the soil will cause leaching beyond the plant's rooting depth. The specific depth in the soil to which chemicals are applied can be determined from the application rate of the irrigation system, the duration of irrigation, soil texture and soil moisture content before the chemigation is applied. (See example 1, Chapter 7)

Table 3.2 can be used to determine the soil moisture content of the soil using the hand feel method. Other methods such as oven drying can be used if accurate measurements need to be made.

Table 3.2 Hand Feel Moisture Test

Degree of Moisture	Feel	Amount of Available Moisture
Dry	Powder dry.	None
Low	Crumbly, won't hold together.	25% or less
Fair	Somewhat crumbly but will hold together.	25 - 50%
Good	Forms ball; will stick slightly with pressure.	50 - 65%
Excellent	Forms a ball, is pliable; sticks readily; a clear water sheen will come to the surface when the ball is squeezed in the hand.	75 - 100%
Too Wet	Can squeeze free water.	Over field capacity

From: Chemigation in the Pacific Northwest, WSU

Table 3.3 shows the depth of penetration into the soil for 1 inch of water application for different soils at various moisture contents.

For example, if an irrigation system is applying 1" of water to a sandy loam soil that has a moisture content at 50% of field capacity, the water applied will move to a depth of 16".

Table 3.3 Depth of Water Penetration (inches) per Inch of Water Applied

Soil Moisture Content	Texture			
	Sand	Sandy Loam	Loam	Clay
	Available Water Storage Capacity			
	1.0 in/ft	1.5 in/ft	2.1 in/ft	2.4 in/ft
75%	48	32	23	20
50%	24	16	12	10
25%	16	11	8	7

Chapter 7 contains further examples of how tables 3.2 and 3.3 are used.

Irrigation System and Injector Calibration

To ensure that the chemical is being applied at the proper concentrations it is important that the application rate and zone flow rates of the irrigation system are known. Over application of chemicals is expensive, is not environmentally friendly and may even be harmful to the crop, defeating the entire purpose of applying the chemical in the first place. Under application may not achieve the desired effect of the chemigation program. Calibration of the injection system to the irrigation system is imperative if the two are to operate harmoniously. See Chapter 7 for further information on calculating injection rates and calibrating various irrigation systems.

Additional information on the design of irrigation systems in the Province of British Columbia can be obtained from the ***B.C. Trickle Irrigation Manual*** and the ***B.C. Sprinkler Irrigation Manual***.

4 Cross Connection Control

4.1 WHY IS CHEMIGATION A POTENTIAL HAZARD ?

The introduction of chemicals into an irrigation system presents a potential hazard to public health. The irrigation system acts as a cross connection between the chemical solution tank and the potable water source. The cross connection can be to an irrigation district mainline, municipal water line, stream, lake, river or groundwater. All of British Columbia's fresh water supplies are considered a potable water source to some user.

A cross connection is any connection or structural arrangement between a potable water system and any non-potable water system or chemical source through which backflow can occur. Any temporary or permanent devices through which backflow can occur are considered cross connections. The water source can be subjected to the chemical being injected into the irrigation system by two backflow processes, backpressure and backsiphonage.

Backsiphonage

Backsiphonage is caused by low pressure or a reduced pressure in the supply piping. Principal causes of backsiphonage are:

- creation of a severe hydraulic gradient by undersized piping in the supply line
- pipeline breakages in the district mainline which is lower than the customer service point
- reduced mainline pressure due to a high water withdrawal rate such as fire fighting or mainline flushing
- reduced mainline supply pressure due to pump or power failure

Backpressure

Backpressure occurs when the user system is operating at a higher pressure than the potable water supply system. Major sources of backpressure are:

- booster pumps on the user system used to increase flows and pressure requirements
- interconnection with other piping systems operating at higher pressures
- connections to pressurized systems such as boilers

In low pressure trickle irrigation systems backpressure can be caused by either elevation differences in the system or chemical injection pumps.

Degree of Hazard

The safety devices that must be installed on an irrigation system will depend on the degree of hazard the system imposes on potable water supplies. There are three degrees of hazard that must be considered.

Severe - An existing or probable cross connection involving any substance in sufficient concentration to cause death, spread disease or has a high probability of causing such effect.

Moderate - An existing or probable cross connection involving any substance that has a low probability of becoming a severe hazard but constitutes a nuisance or is aesthetically objectionable if introduced into the water supply.

Minor - An existing or probable cross connection between a potable water supply line and a tank or other water supply that has a low probability of becoming contaminated.

A chemical injector installed on an irrigation system is considered a severe hazard as fertilizers, herbicides or insecticides can be introduced into the potable water supply system. The irrigation system is generally always cross connected to a potable water supply, whether these are surface water supplies, groundwater, irrigation districts or municipal water systems**. An approved backflow prevention device must be installed on all irrigation systems that are injecting chemicals.**

4.2 BACKFLOW PREVENTION DEVICE SELECTION

There are many types of backflow prevention devices available, some that protect against backsiphonage only and others that protect against both backsiphonage and backpressure. Chemigation systems must use either a double check valve assembly or a reduced pressure backflow device, depending on the water source.

Inspection Requirements

Before the first irrigation application of the season, the owner or operator must have the backflow prevention device inspected by a Certified Tester to ensure that it is an approved device, installed correctly and in proper operating condition. A copy of the test report should be provided to the Water Authority within 30 days of completion of the test and before operation of the chemical injection system.

The owner or operator must provide to the Water Authority upon initial installation of the backflow prevention device a certificate showing:

- date of installation
- type, model and size of backflow prevention device installed
- copy of the Certified Tester's inspection certificate

Nonapproved Backflow Devices for Chemigation

An atmospheric vacuum breaker or a pressure vacuum breaker does not provide adequate protection against all forms of backflow and are therefore not considered approved backflow prevention devices for a chemigation system.

An atmospheric vacuum breaker (AVB) allows air to enter the downstream line when the line pressure is reduced to a gauge pressure of zero or less. The AVB must be installed downstream of the last shutoff valve (no valves can be installed downstream of the AVB) and a minimum of 15 cm (6 inches) above the highest outlet on the non-potable system. **An AVB must not be used where continuous operating pressure is applied for more than 12 hours in any 24-hour period as the relief valve may stick in the closed position and cause malfunctioning.**

The pressure vacuum breaker (PVB) has an atmospheric vent valve which is internally loaded by a spring. A spring helps open the valve and the PVB can therefore be installed on the pressure side of a shutoff valve and used in situations that are operating under continuous pressure. A PVB must be installed 30 cm (12 inches) above the highest outlet on the non-potable water system.

Acceptable uses for atmospheric and pressure vacuum breakers include situations where non-potable water is pumped into an irrigation system that is cross connected to an irrigation district or municipal pipeline or irrigation system applications that do not have a chemigation system installed. Common applications are on automatic home or industrial underground sprinkler systems and agricultural trickle and sprinkler irrigation systems that do not use chemigation systems.

Vacuum breakers are effective against backsiphonage only and cannot be used in backpressure situations.

Approved Backflow Devices for Chemigation

Double Check Valve Assembly

A double check valve assembly (DCVA) consists of two approved check valves, internally loaded either by a spring or weight, which are installed as a unit between two tightly closing shut-off valves. The DCVA is effective against backflow caused by backpressure or backsiphonage. **A DCVA provides acceptable protection from backpressure and backsiphonage for irrigation systems with an approved chemigation system that use a stream, river, lake or other natural surface water source as a water supply.**

The DCVA must be installed upstream of the chemical injection system at a location that is readily accessible for testing purposes.

Figure 4.1 shows the configuration of a double check valve assembly.

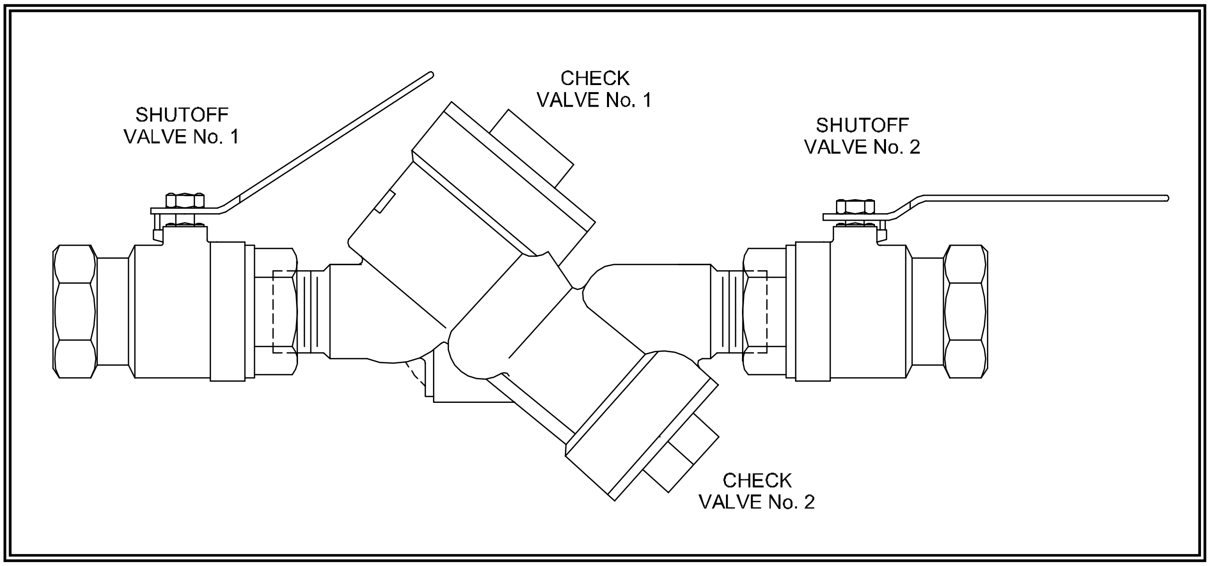

Figure 4.1 **Double Check Valve Assembly**

DCVA Installation for Irrigation Systems

1. Wherever possible the DCVA shall be installed above ground with adequate space to simplify maintenance and testing. It shall be inspected and tested after installation to ensure it is installed correctly and operating satisfactorily.

2. The DCVA must be tested by a Certified Tester before every irrigation season.

3. If possible a DCVA should not be installed in a pit because any leaky test cocks would then become cross connections when the pit is flooded. If the unit must be installed in a pit, provisions for pit drainage must be provided. Test cock tappings should also be plugged to reduce the danger of leaks if the device does become submerged. The vault should be large enough to provide free access for testing or repairing the device.

4. DCVA's larger than 2 1/2" shall have support blocks to prevent damage.

5. A strainer with a blow out tapping should be installed ahead of the DCVA.

6. The DCVA must be drained in the fall and protected from freezing. The manufacturer can provide recommendations on how to drain each water trapping cavity of the device.

7. The lines should be thoroughly flushed before installation of the DCVA. Most failures during testing are due to debris fouling either the first or second check valve seats.

Figure 4.3 and Figure 4.4 provide details on acceptable methods of installing a DCVA on an irrigation system.

Reduced Pressure Principle Backflow Prevention Device

A reduced pressure principle backflow device (RPBD) consists of two independently acting, internally loaded check valves separated by a reduced pressure zone. The device should be installed as a unit between two tightly closing shut-off valves. The RPBD is effective against backflow caused by backpressure and backsiphonage and is designed to be used in situations that are considered very hazardous.

An RPBD should be used as a backflow prevention device for any irrigation system using an approved chemigation system that is drawing water from an irrigation district mainline, municipal waterline, well or other groundwater source.

Figure 4.2 shows a typical reduced pressure principle device.

RPBD Installation for Irrigation Systems

1. The preferred method for a RPBD is to be installed above ground with adequate space to ease maintenance and testing. It shall be inspected and tested after installation to ensure it is installed correctly and operating satisfactorily.

2. The RPBD must be tested by a Certified Tester before every irrigation season.

3. **If possible, the RPBD should not be installed in a pit below ground level.** Flooding of the pit could cause a direct cross connection through the relief valve. If installation in a pit is absolutely necessary, adequate drainage must be provided.

4. RPBD's larger than 2 1/2" shall have support blocks to prevent damage.

5. Horizontal installation of the RPBD is suggested.

6. The RPBD should be hydraulically sized to avoid excessive pressure loss.

7. Because of the nature of a reduced pressure backflow preventer, fluctuating supply pressures on an extreme low flow or static flow condition may cause nuisance dripping and eventual fouling of the device.

8. A strainer with a blow out tapping should be installed ahead of the RPBD.

9. The RPBD must be drained in the fall and protected from freezing. The manufacturer can provide recommendations on how to drain each water trapping cavity of the device.

10. The lines should be thoroughly flushed before installation of the RPBD. Most failures during testing are due to debris fouling either the first or second check valve seats.

Figure 4.3 and Figure 4.4 provide information on the proper installation of an RPBD on an irrigation system.

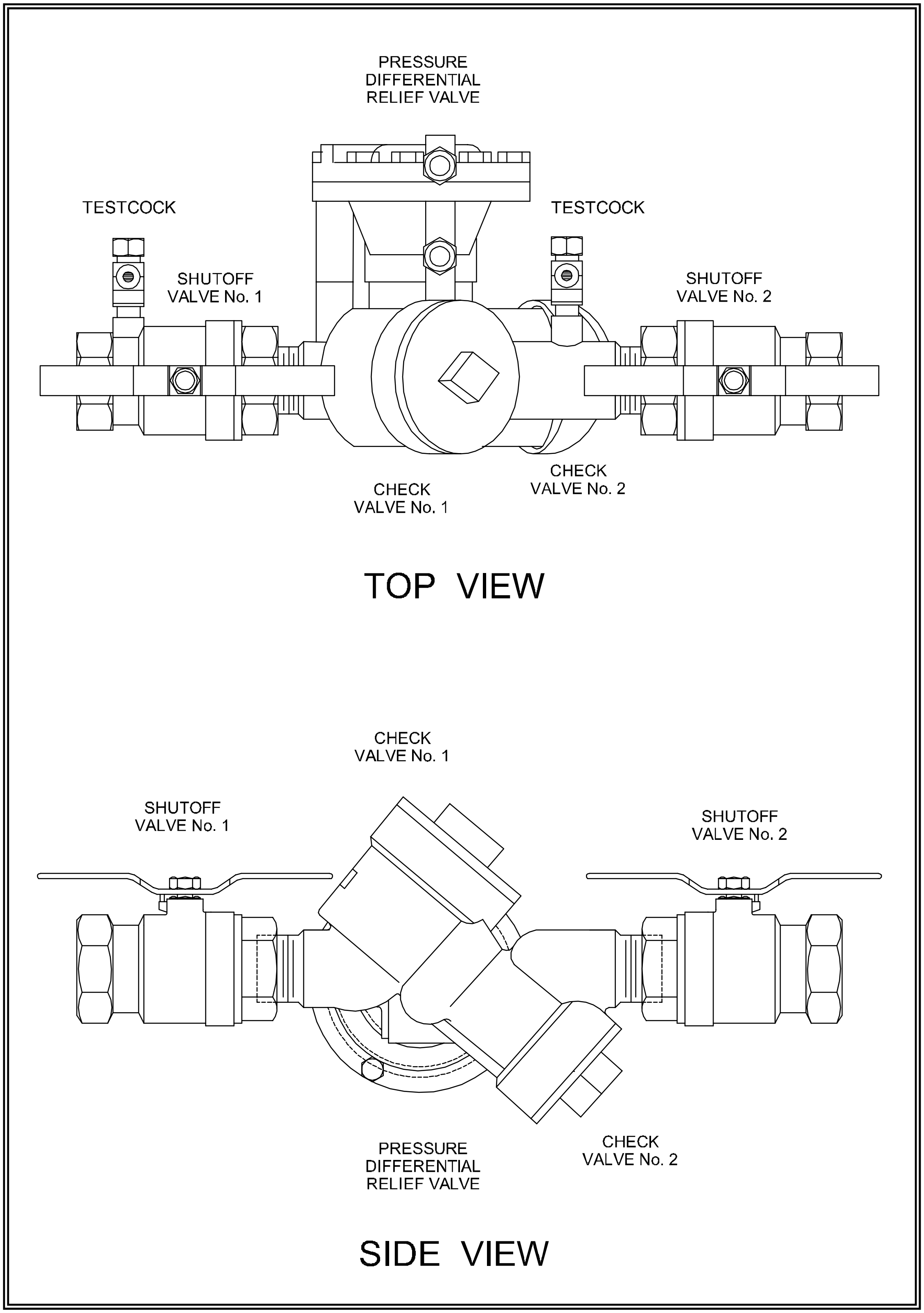

Figure 4.2 Reduced Pressure Backflow Prevention Principle Device

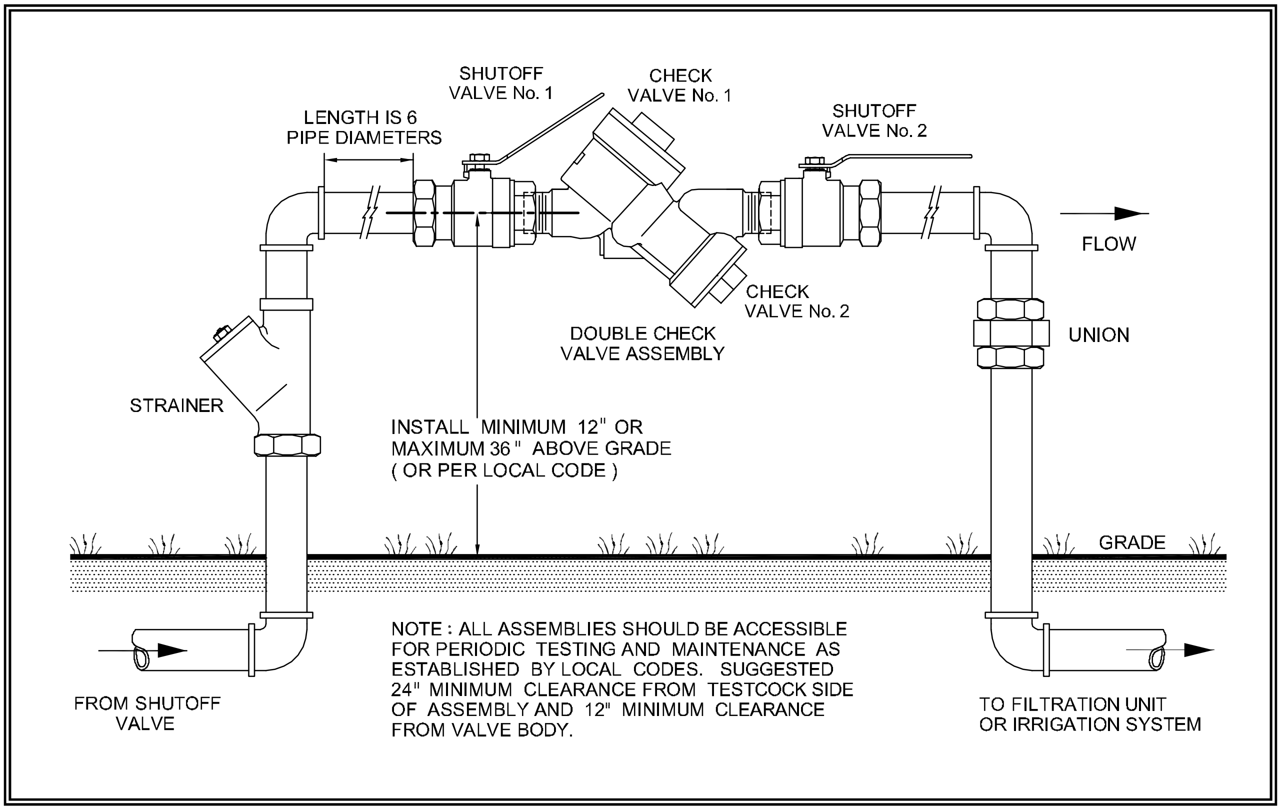

Figure 4.3 **DCVA or RPBD Installation - Above Ground**

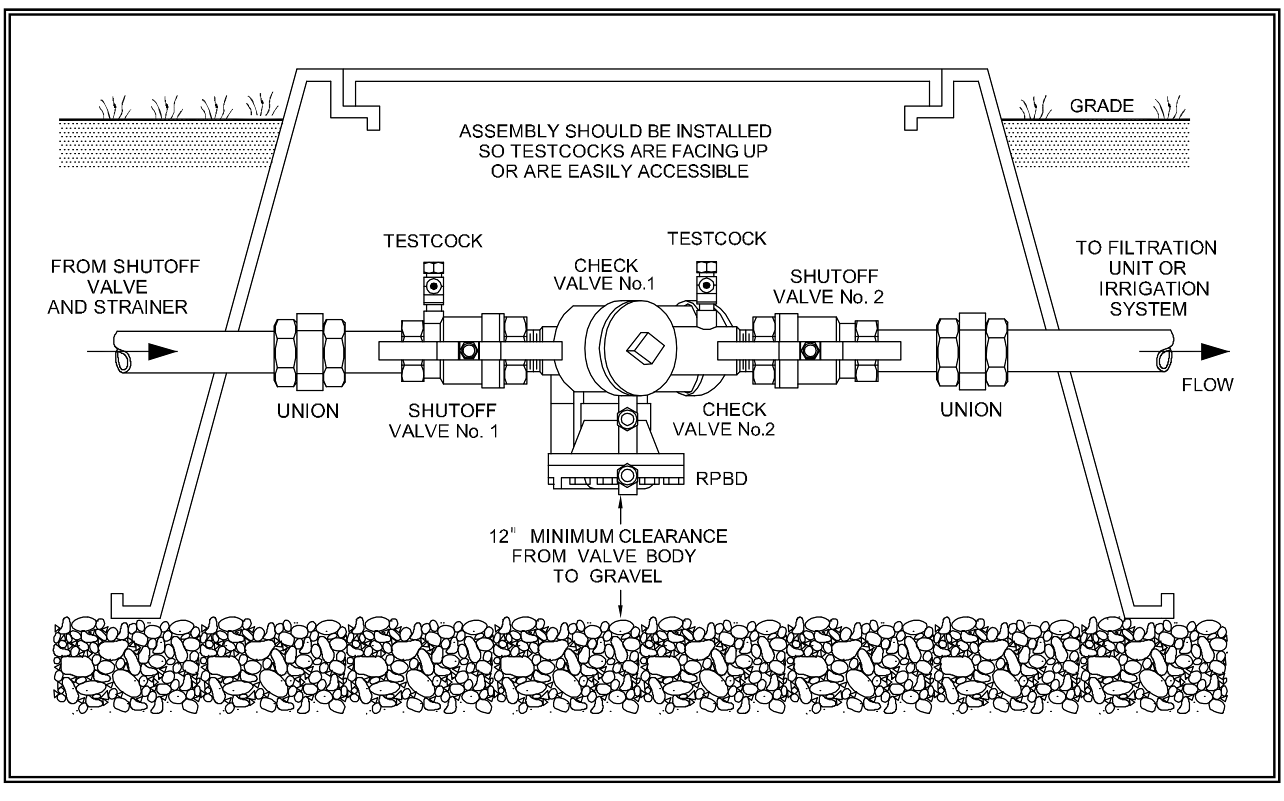

Figure 4.4 **DCVA or RPBD Installation - Below Ground**

4.3 GUIDELINES FOR PESTICIDE, HERBICIDE AND INSECTICIDE APPLICATION

The safety requirements for chemigation systems will depend on many circumstances. These include:

- water supply source
- irrigation system pressure source
- type of injector
- chemical injected
- type of irrigation system

Application of pesticides, herbicides and insecticides is considered much more hazardous than general fertigation. Precautions outlined in this section must therefore be taken for the application of these products. Chemigation systems applying any product must follow all the safety standards outlined in various sections of this manual. If applying a pesticide, herbicide or insecticide the following procedures must be followed:

- ***The product label must clearly specify that the product can be applied through an irrigation system. Applying a product through an irrigation system that does not have this method of application specified on the label is an offense under the Pesticide Control Act.***

- Pesticides, herbicides, insecticides, fertilizers or surfactants when applied through an irrigation system cannot be mixed or combined with other products.

- Only positive displacement pumps or venturi injection systems that are compatible with the chemical to be injected can be used for these products.

- Irrigation must not be carried out for at least 24 hrs after chemigation has been completed.

- Application of these chemicals through an irrigation system cannot occur if the target area is within 30 metres of a residential dwelling, park, playground, stream, river, or lake.

- For pesticide or insecticide application the irrigation system must be capable of covering the entire field in one day. **Solid set sprinkler or center pivot systems are therefore the only acceptable types of irrigation systems that can be used with these products**. The irrigation system must be operated at normal pressures as recommended by the manufacturer. Non-uniform distribution of treated water can result in crop injury, ineffective application or illegal pesticide residues in the crop. The application rate and coefficient of uniformity of the irrigation system must be known before chemigation is attempted.

- Application must be done under minimal wind conditions to allow good distribution, prevent drift and minimize evaporation of the product. Wind conditions must be less than 2 km/hr during the entire time of application to prevent drift off the target area.

- A person knowledgeable of the irrigation system and responsible for its operation must be present during the treatment application to stop pesticide injection and make necessary adjustments should the need arise.

4.3 INJECTION SYSTEM REQUIREMENTS

The following guidelines should be followed to ensure that an injection system is installed in a safe and correct manner.

- *Injection on the suction side of the irrigation pump is prohibited. The injector must be located on the discharge side of the irrigation pump downstream of the backflow preventer.*
- **Only positive displacement pumps or venturi injection systems that are compatible with the chemical to be injected can be used with pesticides, herbicides and insecticides.** Pitot tube or pressure differential injection systems may be used with fertilizers.
- The injection system could shut off unexpectedly while the irrigation system continues to operate. Overflow of the tank could occur resulting in chemicals being spilled onto the ground. The chemical injection line must contain a functional, automatic quick closing check valve to prevent the flow of water from the irrigation system back through the injector into the chemical storage tank.
- A functional, normally closed solenoid valve should be located on the intake side of the injector and be interlocked with the power system and irrigation controller to prevent fluid from being withdrawn from the chemical supply tank when the irrigation system is shut down. The solenoid valve can be interlocked directly with the irrigation controller if an electric injector pump or irrigation pump are not used on the system.
- If an electric irrigation pump is used on the irrigation system and an electric positive displacement pump is used to inject the chemicals, the controls for the injector and irrigation pump must be functionally interlocked to automatically stop chemical injection when the irrigation pump shuts down. This applies to injection systems operating with any type of chemical.

Figure 4.5 shows a schematic of the injection system safety features if the irrigation system includes an irrigation pump and injector pump.

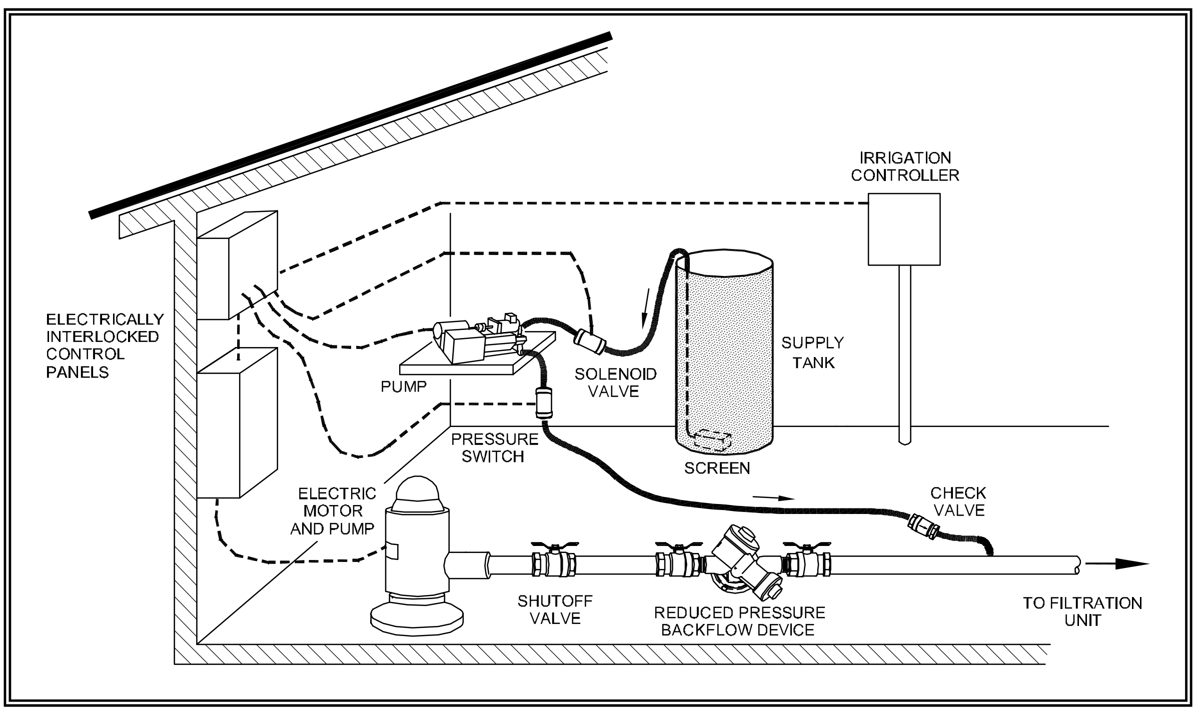

Figure 4.5 Injection System Safety Features

4.5 BACKFLOW PREVENTION REQUIREMENTS

1. Pumping Systems from A Self Contained Pond or Reservoir

Some irrigation systems in British Columbia pump from a self contained storage reservoir that is filled from a ditch or stream by a lift pump.

If the water source is a self contained pond or reservoir, a 50-cm air gap must be maintained between the maximum water surface elevation of the pond and the pipeline used to fill the pond. If the air gap cannot be maintained, then a Double Check Valve Assembly must be installed according to the procedures shown in Section 4.2.

The irrigation pump discharge line must contain a functional quick closing check valve and a vacuum breaker and drain located between the pump and check valve to prevent the backflow of treated irrigation water into the pond or reservoir.

The irrigation pumping system must contain a functional pressure switch that will shut down the irrigation pump should the system pressure reach a point where chemical distribution is adversely affected. A foot valve shall also be installed on the suction line to prevent the suction line from draining back into the water source.

The guidelines shown under pesticide application and injection system requirements shall also apply as shown in those sections.

2. Pumping Systems from Streams, Lakes or Other Natural Watercourses

*If the irrigation system is pumping directly from a canal, drainage or irrigation supply ditch, lake, stream or other natural watercourse an approved **Double Check Valve Assembly Backflow Prevention Device*** must be installed on the irrigation mainline between the irrigation pump and the injection system.

In addition to the Double Check Valve Assembly the pumping system must include a foot valve on the suction line.

The irrigation pumping system must contain a functional pressure switch that will shut down the irrigation pump should the system pressure reach a point where chemical distribution is adversely affected.

The guidelines shown under pesticide application and injection system requirements shall also apply as indicated in those sections.

3. Pumping Systems from Wells

An irrigation system drawing from groundwater must install an approved ***Reduced Pressure Principle Backflow Device*** *between the irrigation pump and the chemical injector.*

In addition to the Reduced Pressure Principle Backflow Device the pumping system must have a foot valve at the bottom of the intake line to prevent the discharge column from draining back into the water source.

The irrigation pumping system must contain a functional pressure switch that will shut down the irrigation pump should the system pressure reach a point where chemical distribution is adversely affected.

The guidelines shown under pesticide application and injection system requirements shall also apply as indicated in those sections.

4. Pumping Systems from Irrigation Districts or Other Water Authorities

If the irrigation system is pumping from an irrigation district or other water purveyor mainline an approved ***Reduced Pressure Principle Backflow Device*** *must be installed between the water authority's mainline and the irrigation pump.*

In addition to the Reduced Pressure Principle Backflow Device the pumping system should include a check valve on the discharge side of the irrigation pump.

The irrigation pumping system must contain a functional pressure switch that will shut down the irrigation pump should the system pressure reach a point where chemical distribution is adversely affected.

The guidelines shown under pesticide application and injection system requirements shall also apply as indicated in those sections.

5. Irrigation Systems Operating from Irrigation District or Municipal Mainlines

If the irrigation system is operating directly from an irrigation district or other water purveyor mainline an approved ***Reduced Pressure Principle Backflow Device*** *must be installed between the irrigation district service and the chemical injector system.*

The guidelines shown under pesticide application and injection system requirements shall also apply as shown in those sections.

6. Irrigation Systems Operating on a Self Contained Gravity Feed System

An irrigation system operating on its own gravity feed system where the elevation difference between the irrigation intake and the chemical injector exceeds 10 m, need not use a backflow prevention device if a venturi or other passive type of injector is used. If an injector pump is used, the elevation difference between the intake and the injector must exceed the pressure capability of the injector pump, otherwise a DCVA assembly must be installed between the intake and the chemical injector.

If the gravity feed irrigation system also functions as a potable water source, then injection must take place downstream from the potable connection and a DCVA must be installed between the injector and the potable water connection on the water supply mainline.

The guidelines shown under pesticide application and injection system requirements shall also apply as shown in those sections.

4.6 ADDITIONAL PRECAUTIONS

Personal Protection

The use of insecticides, nematicides and other chemicals are hazardous and require that safety procedures be followed by the operator. The following precautions should be taken by chemigation operators:

Wear rubber boots, gloves and other appropriate protective equipment at the injection site.

Use a separate injection system to apply insecticides from that used to apply fertilizers.

Read the label to determine the safe field re-entry interval.

Ensure that the injection site is out of the spray range of the irrigation system. Some sprinklers may have to be plugged to ensure the injection site or the operators are not wetted down.

Field Posting

Children, farm workers and other people may be tempted to take a drink from an irrigation sprinkler or trickle emitter on a hot summer's day. The orchard should be posted with signs warning that the water cannot be consumed if fertigation or any other form of chemigation is done.

> NOTE
>
> A backflow prevention device is only considered to be in working order if it is tested annually by a certified technician.

5 Chemical Selection

5.1 SELECTION CRITERIA

Many factors must be considered when selecting a chemical for injection into an irrigation system. These include:

- **Solubility of chemical.** The chemical must be readily soluble in water and stay in solution during storage and the application process.
- **Desired effect of chemical applied.** The chemical to be applied must achieve the desired effect with this method of application.
- **Effect of chemical on soil.** Addition of some fertilizers may increase the acidity of the soil in the treated area, especially under a trickle irrigated regime.
- **Type of irrigation system.** The uniformity, application efficiency and distribution method of the irrigation system are all important in determining if the chemical to be applied is compatible with the irrigation system.
- **Compatibility of chemical with water source.** Chemicals that react with elements in the water supply after being injected should be avoided.
- **Determination of chemical or nutrient mixes.** Two or more chemicals that are either mixed or applied simultaneously must not react with each other to form a precipitate.
- **State of chemical.** Whether the chemical is in the solid or liquid state will determine handling, injection method and injection rates.

This chapter will provide some guidance on the selection of various chemicals for injection into an irrigation system.

5.2 FERTILIZERS

Selection of fertilizers can be difficult as fertilizers come in various chemical formulations containing composition agents with different types of coatings, including wax. Fertilizers are available in solid or liquid forms. The selection of a solid or liquid fertilizer will depend on storage requirements, available facilities, product stability, ease of handling, method of injection, cost, and the acidification produced by applying the fertilizer to the soil.

Table 5.1 provides information on the calcium carbonate equivalent for various fertilizers. The amount of calcium carbonate required to neutralize the acidity produced by a given quantity of fertilizer product is the calcium carbonate equivalent. The relative acidifying potentials of fertilizers can be found by comparing the calcium carbonate equivalents.

Based on their primary nutrient content (N, P_2O_5, K_20), fertilizers are given a designation consisting of three numbers. These numbers, called grade, represent the amount of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) content of the fertilizer in terms of percentage by weight. The fertilizer ratio is the relative proportion of each of the primary nutrients. For example, a 12-12-12 grade fertilizer has a 1:1:1 ratio.

To avoid damage to plant roots from high fertilizer concentrations, fertilizer concentration in the irrigation water should not exceed 5%. Although susceptibility to root burning from concentrated fertilizers varies with crops, fertilizers or accompanying irrigation practices, this upper limit should not be exceeded to ensure save application. Generally, fertilizer concentrations of 1-2% in the irrigation water are considered acceptable. Examples showing how to calculate this percentage are shown in chapter 7.

Solid Fertilizers

To be able to apply a granular fertilizer through an irrigation system it must first be dissolved in water. The mass of fertilizer that will dissolve in a specific volume of water is known as solubility. Table 5.1 provides the solubility of some fertilizers in water at various temperatures. The solubility of fertilizers may vary greatly with temperature, especially ammonium and potassium nitrates. If the solubility of the fertilizer at ambient air temperatures is known those values should be used. Table 5.1 can be used to provide a good estimate by interpolating data. The presence of other substances in the solution may either decrease or increase the solubility.

Selection of a granular fertilizer will depend on the nutrient that is to be applied, fertilizer solubility and ease of handling. To ensure that fertilizers selected will not precipitate in the irrigation lines, mix the fertilizer solution with a sample of irrigation water in the same proportions as when they are mixed in the irrigation system. If the chemical stays in solution, then the product is safe to inject into the irrigation system. If a precipitate occurs, applying this chemical through fertigation should be avoided.

Liquid Fertilizers

Liquid fertilizers in the past have generally been considered more expensive and offered only lower nutrient concentrations. As the demand for liquid fertilizers has increased, this may no longer be true, with liquid fertilizers offering many intrinsic advantages.

Liquid fertilizers are available as fertilizer solutions and suspensions, both of which may contain multinutrient or single nutrient materials. Solutions are defined as liquids that have all the plant nutrients in a solution while suspensions hold part of the plant nutrients suspended in the liquid by a suspending agent. Liquid fertilizers offer several advantages over solids.

1. Liquids are especially suited to application through a trickle or sprinkler irrigation system.
2. Liquids are excellent carriers of herbicides.

Table 5.1	Granular Fertilizer Properties				
Fertilizer	**Molecular Compound**	**% Element**	**Solubility g/100 g H_2O**	**Temp °C**	**Equivalent $CaCO_3$**
Ammonia	NH_3	82% N	90	0	148
Ammonium Nitrate	NH_4NO_3	34% N	118 187 590	0 20 80	62
Ammonium Sulphate	$(NH_4)_2SO_4$	21% N 24% S	71 95	0 80	110
Calcium Carbonate (Limestone)	$CaCO_3$		0.006	0	
Calcium Metaphosphate	$Ca(PO_3)_2$		0.001	0	
Calcium Nitrate	$Ca(NO_3)_2 . 4H_2O$	15.5% N	134 364	0 100	-20
Calcium Sulphate	$CaSO_4 . 2H_2O$		0.24	0	
Copper Sulphate	$CuSO_4 . 5H_2O$		32	0	
Diammonium Phosphate	$(NH_4)_2HPO_4$	18% N 20% P	25	0	70
Dicalcium Phosphate	$CaHPO_4 . 2H_2O$		0.02	0	
Magnesia	MgO		0.0006	0	
Magnesium Sulphate	$MgSO_4 . 7H_2O$		85	0	
Manganese Sulphate	$MnSO_4 . 4H_2O$		105	0	
Monoammonium Phosphate	$NH_4H_2PO_4$	11% N 22% P	43	0	58
Monocalcium Phosphate	$CaH_4(PO_4)_2H_2O$	20% P	varies		
Potassium Chloride	KCl	60% K_2O	28 51	0 80	neutral
Potassium Nitrate	KNO_3	13% N 46% K_2O	13 169	0 80	- 26
Potassium Sulphate	K_2SO_4	53% K_2O	8	0	neutral
Sodium Nitrate	$NaNO_3$	16% N	73	0	- 29
Urea	$CO(NH_2)_2$	46% N	67 108 167	0 20 40	71
Zinc Sulphate	$ZnSO_4 . 6H_2O$		70	0	

3. Liquids are excellent carriers of micronutrients. If applied through a trickle irrigation system, liquid fertilizers allow for accurate placement of the micronutrient at the desired location for efficient fertilizer use.

4. Plant utilization of the nutrient is more efficient as the nutrients are in a form that is readily available to the roots.

Various fertilizer solutions are shown in table 5.2.

Suspensions have some additional advantages over solutions.

1. Production costs are lower because less materials are used to produce suspensions.
2. Higher analysis fertilizers can be produced, especially for grades containing potassium.
3. Larger quantities of micronutrients can be added to suspensions than solutions.

Take care with suspensions that contain powdered herbicides and insecticides. When injected into an irrigation system these chemicals may come out of solution due to the dilution of the suspension material.

Typical grades of clear liquid fertilizers and suspensions that are available from suppliers are shown in table 5.3. A discussion on each type of nutrient follows.

Nitrogen Fertigation

Most commercially available forms of nitrogen fertilizer are readily soluble in water and can therefore be used for fertigation purposes. Inert conditioners used as anti-caking agents in some solid nitrogen fertilizers may cause clogging problems if injected into a trickle irrigation system. Homemade fertilizer solutions made by dissolving granular fertilizers should be checked carefully to ensure that all the material is soluble and remains in solution.

Proper application of nitrogen fertilizers and solution mixes by fertigation requires a thorough understanding of the available forms of nitrogen. Many mixes may contain nitrogen in more than one form. Movement of nitrogen nutrients through the soil profile and uptake by the crop will depend upon the forms available and the percentage of each form.

Urea (46-0-0) is a highly soluble form of nitrogen fertilizer. In water solutions it acts as a neutral molecule and does not ionize. Urea is often mixed with ammonium nitrate to form a concentrated liquid solution for fertigation. Such mixtures cause only slight Ph shifts in the irrigation water. Urea molecules tend to stay in the soil solution and move in the same direction as the irrigation water. However, urea undergoes hydrolysis with an enzyme in the soil and forms ammonium. Ammonium is relatively immobile in the soil. Therefore urea placement into the root zone can be achieved with proper irrigation water management. Accurate placement of trickle fertigated urea will depend on the emitter discharge rate, irrigation frequency and the exchange capacity and physical properties of the soil.

Table 5.2	**Fertilizer Solutions**		
Fertilizer Solution	**% Nutrient**	**Density Kg/Litre**	**Density Lbs/Gal (U.S.)**
	Nitrogen		
Urea Solution (23%)	23% N	1.14	9.48
Urea Solution (20%)	20% N	1.12	9.33
Ammonium Nitrate	20% N	1.27	10.56
N Solution	30% N	1.27	10.56
Urea Ammonium Nitrate	28% N	1.28	10.66
Urea Ammonium Nitrate	32% N	1.33	11.06
Ammonium Nitrate Ammonia	37% N	1.19	9.91
Ammonium Nitrate Ammonia	41% N	1.14	9.48
Calcium Ammonium Nitrate	17% N		
Aqua Ammonia	20% N	0.91	7.60
Aqua Ammonia	24% N	0.90	7.47
	Phosphorus		
Phosphoric Acid	52% P_2O_5 68% P_2O_5 75% P_2O_5		
Ammonium PolyPhosphate	8% N 24% P_2O_5	1.26	10.5
Ammonium PolyPhosphate	9% N 30% P_2O_5	1.36	11.3
Ammonium PolyPhosphate	10% N 34% P_2O_5	1.37	11.4
Ammonium PolyPhosphate	11% N 37% P_2O_5	1.41	11.7
	Potassium		
Potassium Ammonium Phosphate	15% N 15% P_2O_5 10% K_2O		
Potassium Ammonium Phosphate	10% N 10% P_2O_5 10% K_20		
Potassium Ammonium Phosphate	15% N 8% P_2O_5 4% K_2O		

From Western Fertilizer Handbook

Ammonium sulphate (21-0-0) and **calcium nitrate** (15-0-0) are relatively soluble and do not cause a large pH change in irrigation water. Ammonium sulphate however is very acidifying once in contact with the soil. In the soil, NH_4^+ is nitrified to form NO_3^- plus 4 H^+ ions that increase soil acidity. The nitrification process occurs very quickly in warm moist soils such as under a trickle irrigation emitter.

Anhydrous ammonia (82-0-0), under normal air pressure is a gas but is kept in a liquid form under its own vapour pressure in closed tanks. When dissolved in water anhydrous ammonia forms **aqua-ammonia** (24-0-0). Anhydrous ammonia is classified as a hazardous material and is not recommended for fertigation. Aqua-ammonia when injected into an irrigation system may volatilize gaseous ammonia and result in lower fertilizer efficiency. Ammonia will also increase the pH of the fertilizer solution, increasing the chances of calcium or magnesium precipitates forming. Ammonia fertilizers that are applied through fertigation systems tend to concentrate immediately below the soil surface because ammonia or ammonium are relatively immobile in the soil. In situations where the soil surface temperature is high and alkaline soil conditions persist, ammonium accumulated at the surface is susceptible to losses by volatilization. For trickle fertigation systems this loss can be reduced by using a plastic or other mulch system.

Nitrate nitrogen moves freely with the irrigation water and accumulate at the periphery of the wetted soil volume as subsequent irrigations are applied. Proper irrigation system management is required to ensure that nitrates are not leached beyond the plant's active root zone where uptake of the nutrient is no longer possible. Leaching of nitrate nitrogen into groundwater is also a concern. When applying with a sprinkler irrigation system, nitrate nitrogen should be applied near the end of the irrigation set, allowing for at least one hour of irrigation after injection has completed. This will reduce volatilization losses and provide a better opportunity for incorporating nitrate nitrogen into the soil.

Table 5.3 Typical Grades of Clear Liquid Mixes and Suspensions

Ratio	Grade	
	Clear Liquid Mix	Suspension
3:1:0	24-8-0	27-9-0
2:1:0	22-11-0	26-13-0
1:1:0	19-19-0	21-21-0
1:1:1	8-8-8	15-15-15
1:2:2	5-10-10	10-20-20
1:3:1	7-21-7	10-30-10
1:3:2	5-15-10	9-27-18
1:3:3	3-9-9	7-21-21

From Western Fertilizer Handbook

Phosphorus Fertigation

Many forms of phosphorus fertilizers, while soluble in water, react easily with calcium and magnesium in the water to create precipitates that can clog trickle lateral lines and emitters. For example, **treble super phosphate** (0-45-0) changes spontaneously to dicalcium phosphate when in a solution that readily precipitates. Fertigation of this fertilizer is therefore not recommended.

Ammonium phosphates, such as ammonium phosphate sulphate (16-20-0), monoammonium phosphate (11-48-0) and diammonium phosphate (16-46-0) are highly soluble in water and are good sources of phosphorus for fertigation. Experience has shown that many phosphate fertilizers may contain a coating that greatly reduces the ease of solubility. Fertilizers without a coating should be selected.

Phosphoric acid (0-55-0) is also a good source of phosphorus for fertigation and has the added benefit of keeping the pH of the injected solution low enough to reduce the potential of dicalcium phosphate or dimagnesium phosphate from forming.

If fertigation of phosphorus is attempted with irrigation water high in calcium and magnesium the water pH should be kept low. The injection of an acid immediately after the injection of phosphorus is one alternative but the best approach is to select a phosphorus source that is compatible with the irrigation water. A precipitation test should be carried out by mixing the fertilizers to be injected with the irrigation water in the same proportions as when injected into the irrigation system.

Phosphorus is readily adsorbed and precipitated in most soils and is generally considered immobile when applied topically at normal fertilization rates. However concentrated phosphorus solutions applied through a trickle irrigation system may move as far as 20 cm horizontally and 30 cm vertically from the emitter drip point.

Potassium Fertigation

Most commercially available potassium fertilizers such as potassium chloride, potassium sulphate, and potassium nitrate are all highly soluble in water of any pH value. Heating the stock solution may be required to get potassium sulphate to completely dissolve. Potassium sulphate and potassium nitrate may be preferred over potassium chloride on fruit crops and strawberries that may be chloride sensitive. Potassium is easily applied through most types of fertigation systems.

Potassium is absorbed in the soil by cation exchange similar to ammonium. However, since the potassium ion (K^+) has a lower affinity for the soil colloid surface than does the ammonium ion (NH_4^+), considerable movement of potassium through the soil can be achieved when applied through trickle irrigation systems.

Micronutrients

The major concern of micronutrient fertigation is the high affinity of the cationic micronutrients to the soil particles. Fertigated micronutrient elements may not move far enough to achieve proper placement in the root zone. Foliage spray of micronutrient elements is most often the recommended means of application.

Table 5.4 Inorganic Sources of Micronutrients				
Material		**Element (%)**	**Water Solubility (g/100g H_20)**	**Temp ^0C**
Sources of Boron				
Granular Borax	$Na_2B_4O_7 \cdot 1OH_2O$	11.3	2.5	1
Sodium Tetraborate, Anhydrous	$Na_2B_4O_7$	21.5	1.3	0
Solubor®	$Na_2B_8O_{13} \cdot 4H_2O$	20.5	22	30
Ammonium Pentaborate	$NH_4B_5O_8 \cdot 4H_2O$	19.9	7	18
Sources of Copper				
Copper Sulfate	$CuSO_4 \cdot 5H_2O$	25.0	24	0
Cuprous Oxide	Cu_2O	88.8	i[1]	
Cupric Oxide	CuO	79.8	i[1]	
Cuprous Chloride	Cu_2Cl_2	64.2	1.5	25
Cupric Chloride	$CuCl_2$	47.2	71	0
Sources of Iron				
Ferrous Sulfate	$FeSO_4 \cdot 7H_2O$	20.1	33	0
Ferric Sulfate	$Fe_2(SO_4)_3 \cdot 9H_2O$	19.9	440	20
Iron Oxalate	$Fe_2(C_2O_4)_3$	30.0	very soluble	
Ferrous Ammonium Sulfate	$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$	14.2	18	0
Ferric Chloride	$FeCl_3$	34.4	74	0
Sources of Zinc				
Zinc Sulfate	$ZnSO_4 \cdot H_2O$	36.4	89	100
Zinc Oxide	ZnO	80.3	i[1]	
Zinc Carbonate	$ZnCO_3$	52.1	0.001	16
Zinc Chloride	$ZnCl_2$	48.0	432	25
Zinc Oxysulfate	$ZnO \cdot ZnSO_4$	53.8		
Zinc Ammonium Sulfate	$ZnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	16.3	9.6	0
Zinc Nitrate	$Zn(NO_3)_2 \cdot 6H_2O$	22.0	324	20
Sources of Molybdenum				
Sodium Molybdate	$Na_2MoO_4 \cdot H_2O$	39.7	56	0
Ammonium Molybdate	$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	54.3	44	25
Molybdic Oxide	MoO_3	66.0	0.11	18

Table 5.4	Inorganic Sources of Micronutrients			
Sources of Manganese				
Manganous Sulfate	$MnSO_4 \cdot 4H_2O$	24.6	105	0
Manganous Carbonate	$MnCO_3$	47.8	0.0065	25
Manganese Oxide	Mn_3O_4	72.0	i[1]	
Manganese Chloride	$MnCl_2$	43.7	63	0
Manganese Oxide	MnO	77.4		

[1] An "i" denotes insolubility

From Western Fertilizer Handbook

If micronutrients are to be applied by fertigation it is recommended that trickle irrigation be used. Chelates are very water soluble and a good source of micronutrients for fertigation but may be expensive. Chelates or sulphate salts of micronutrient elements such as iron, zinc, copper and manganese are recommended when applied through a trickle irrigation system. Zinc sulphate may be difficult to dissolve into stock solutions and should therefore be used with caution.

Table 5.4 provides information on inorganic sources of micronutrients.

5.3 HERBICIDES

Solubility

The solubility of herbicides in water varies greatly with the type of herbicide. Solubility is a factor that determines the depth that the herbicide will move in the soil and the amount of herbicide available for absorption by plants from the soil solution. Generally, herbicides with higher water solubilities will be carried to a deeper depth. The more herbicide in the soil solution the more toxic the herbicide will be to the plants.

Volatility

Volatility is the tendency of a liquid to become a gas and increases as the vapour pressure of the liquid increases. Herbicides with a high vapour pressure that are applied through a sprinkler irrigation system may lose too much as a gas before reaching the crop or soil. Evaporation losses from the soil surface are also more rapid with higher vapour pressures.

Adsorption

Herbicides are easily adsorbed on organic matter and clay particles in the soil. Since herbicides vary in their tendency to be adsorbed and the organic matter and clay content will also vary in the soil, adsorption of herbicides for each condition is difficult to predict. Adsorption removes the herbicide from the soil solution and reduces the activity. Herbicides adsorbed on organic matter and clay are not readily decomposed and are therefore more persistent.

Movement of herbicides into the soil depends on solubility, volatility and adsorption. Herbicides will generally move only a fraction of the distance that the water moves. Since most weeds germinate in the top 25 - 50 mm of the soil, the herbicide must be concentrated in this zone. Sufficient water must be applied to move the herbicide into this germination zone but not beyond. If too little water is applied the herbicide would remain near the soil surface where it may be lost by volatilization or breakdown by ultraviolet light. Herbicides are also less active in dry conditions. Moving the herbicides below the soil surface where rapid drying does not readily occur may be more effective.

Sprinklers are the most widely used irrigation systems for applying herbicides although success with application through some forms of trickle irrigation systems with certain chemicals has also been effective. Herbicides, fungicides, nematocides and other kinds of soil fumigants have been applied through trickle irrigation systems with various degrees of success. Spray emitters or undertree irrigation systems are more effective for herbicide application than drip or trickle emitter systems as some herbicides break down quickly once contact with moist soil is made. Application of nematocides through trickle irrigation systems have been very successful. Herbicides and nematicides should never be mixed with any other chemical when injected into an irrigation system. These chemicals may also react with plastics such as PVC pipe. Nematocide emulsions using surfactant type emulsifiers should not be used as surfactants degrade polyethylene pipe.

Careful attention to the safety requirements outlined in chapter 4 and the irrigation system design and operation details provided in chapter 3 should be followed when planning to inject herbicides and chemicals through an irrigation system.

Note:
The product label must specifically show that the product can be applied through an irrigation system before any chemigation is attempted.

Chapter 7 provides information on calculating the injection rates for different types of irrigation systems.

5.4 PESTICIDES

The use of irrigation systems to control insects and pests will depend on the chemical nature of the particular pesticide, special needs of the crop at the various growth stages, and the efficacy of the pesticide when applied through an irrigation system.

Note:
The product label must specifically show that the product can be applied through an irrigation system before chemigation of the product may be attempted. The product label will also show the pest that can be controlled and on which crops the chemical can be applied.

Irrigators must always follow the guidelines shown on the label before applying any pesticide. The safety precautions shown in chapter 4 must always be followed, as should the irrigation system design and operation information in chapter 3. Chapter 7 provides information on calculating injection rates and calibrating various types of irrigation systems.

6 Injection Equipment

The injector is the heart of the chemigation system. There are many types of injectors available, all with their own advantages and disadvantages. Some types of injection systems are not recommended due to the safety hazards that are inherent with those systems. This section provides information on the selection of an appropriate injection system.

6.1 INJECTOR SELECTION

Proper selection of a chemical injector and the chemical solution tank must include consideration of the following:

- type of irrigation system
- crop grown
- irrigation system flow rate
- irrigation system operating pressure
- injection rate
- type of chemical to be injected
- determination of whether a fixed volume ratio of fertilizer to water is needed
- source of power
- duration of operation
- expansion requirements
- safety considerations

Injectors can be classified into two types of feeder systems, constant rate feeders and constant ratio feeders. Constant rate feeders inject at the same discharge rate even if the irrigation system flow rate changes. A constant ratio feeder will inject the chemical at a constant ratio in proportion to the irrigation system flow rate. The concentration of chemical in the irrigation water for a constant ratio feeder will therefore remain the same, and the injection time for each zone will remains constant.

The following steps are useful for the selection of a chemical injector.

1. Determine the flow rate of the largest zone. The injector selected must be capable of injecting sufficient volume to achieve the concentration of chemical desired in the irrigation water. Another check is to ensure that the injector is capable of completely injecting all of the chemical in the desired time frame.

2. Determine operating sequence. Will more than one zone be treated at a time? If so, then a constant ratio feeder may have an advantage in that the injection time for each zone will remains constant. If only one zone at a time is being treated, then it may be more convenient to inject the required weight or volume. A constant rate feeder or diluter works well for this situation.

3. Determine the operating characteristics of the irrigation system. If water is delivered to the irrigation system via a pump, an injector pump must be interlocked with the main irrigation pump. An injector pump must also be capable of exceeding the operating pressure of the irrigation system. A passive injection system may also have different backflow prevention requirements in specific situations. See chapter 4 for further information.

4. Availability of power. The type of injector used will depend on whether an electrical power source is available at the injection site.

5. Determine the type of chemicals that are to be injected. The injector must withstand the corrosivity of the injected chemical.

Injectors can also be categorized into two different types, passive and active injectors. A discussion on the various types of injectors follows.

6.2 PASSIVE INJECTORS

Passive injectors use the energy supplied by the irrigation system or the atmosphere to inject the chemicals. Examples of passive injectors are a venturi, pitot tube, utilization of the suction side of an irrigation pump and taking advantage of pressure differentials.

Injection on Suction Side of Irrigation Pump

A centrifugal pump draws water into the impeller by creating a negative pressure in the suction pipe. Atmospheric pressure then forces water up the suction pipe and into the pump volute. The same principle can be used to draw fertilizer solutions into the irrigation system. This system is risky and potentially hazardous as any chemicals that are being injected during a pump or power failure would then enter the water supply. **This method of injection is not recommended for any chemigation system application in B.C.**

Other problems that can be encountered with this type of injection system are:

- any air entering through the connection to the suction line can cause malfunctioning and damage

- extra pump maintenance may be required due to the metal's exposure to the chemicals.

Diluter Systems

Batch tank or diluter systems are simple, easy to operate but are labour intensive and require good management to ensure that uniformity of application be achieved. Pitot tube and pressure differential injectors are two types of diluter systems.

Pitot Tube Injector

The pitot tube injection system consists of a small open-ended pipe placed in the irrigation pipe with one end facing the water flow and the other facing away from the water flow. (See Figure 6.1) This practice creates a flow of water between the two pipe ends. The water can be circulated through an airtight pressure supply tank that contains the fertilizer or chemical. Dry fertilizers are often used with this injection system.

The rate at which the fertilizer is injected will vary as the fertilizer in the tank becomes diluted. This type of injection system is therefore not applicable to continuously moving irrigation systems such as travelling guns or center pivots. The proper uses of a pitot injector requires that:

- a batch of fertilizer be mixed for each set and that the entire batch is applied during that irrigation set;
- each set is sufficiently long enough to allow all of the fertilizer that is mixed to be applied;
- the supply tank must withstand the maximum operating pressure of the irrigation system.

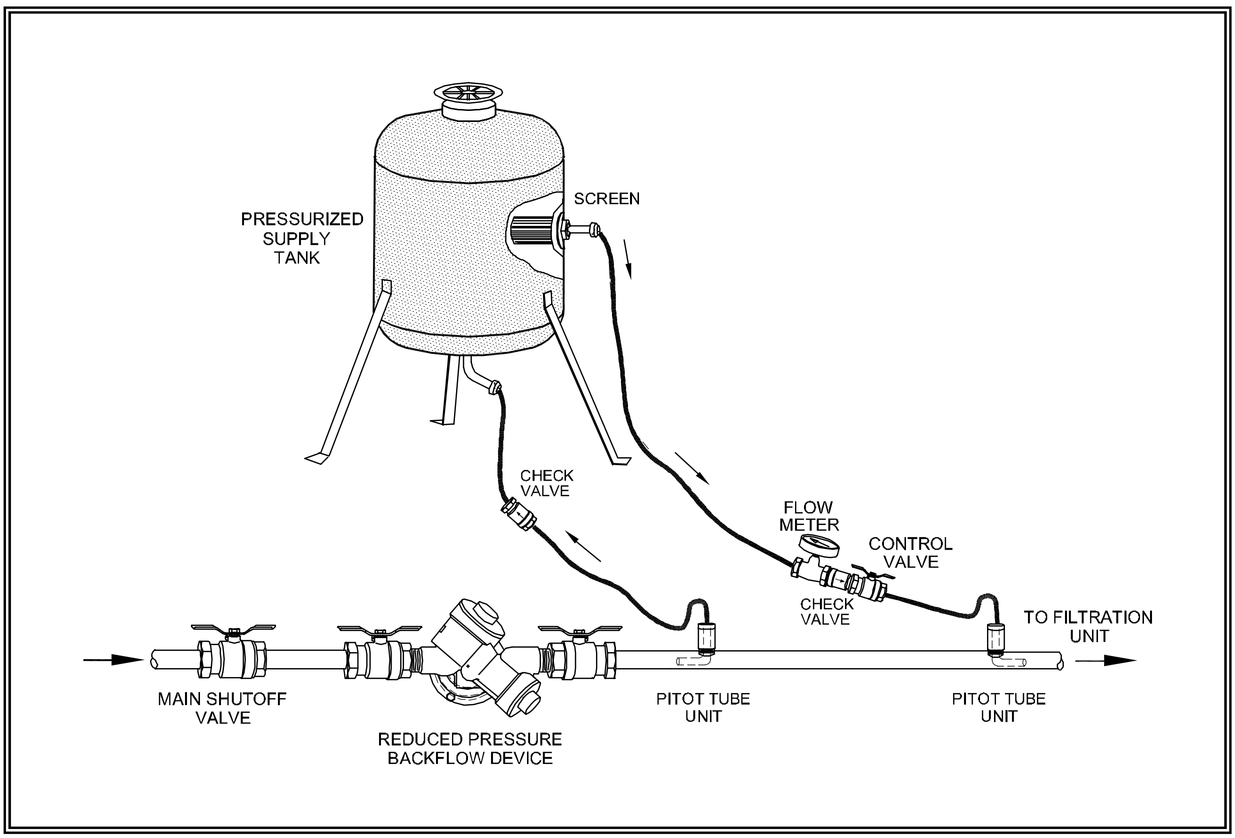

Figure 6.1 **Pitot Tube Injector**

Pressure Differential Injection System

Pressure differential injectors consist of a pressurized tank connected to the irrigation mainline through two ports. This type of injection system is also known as a diluter injection system. The inlet port is connected to the mainline on the upstream side of the pressure reducing valve. The outlet port is connected to the downstream side of the pressure reducing valve. (See Figure 6.2) The pressure reducing valve on the irrigation mainline is used to create a pressure difference between the inlet and outlet ports of the pressurized tank. The difference in pressure creates a flow of water through the tank. The chemical in the tank is slowly diluted over the injection time until it has all been applied.

This type of injection system is used where a specified amount of chemical is to be applied to an irrigated zone. As the chemical is diluted over time, the injector cannot be operated if the irrigation system is switching from one zone to another. A new chemical mixture must be added to the injector every time a new zone is irrigated. This type of injection system is trouble-free and inexpensive and works well for small systems operating at less than 50 gpm.

Pressure differential systems are also available with a diaphragm to separate the incoming water from the fertilizer. The concentration of the injected solution then remains the same. This type of system is generally used for smaller operations such as small greenhouses.

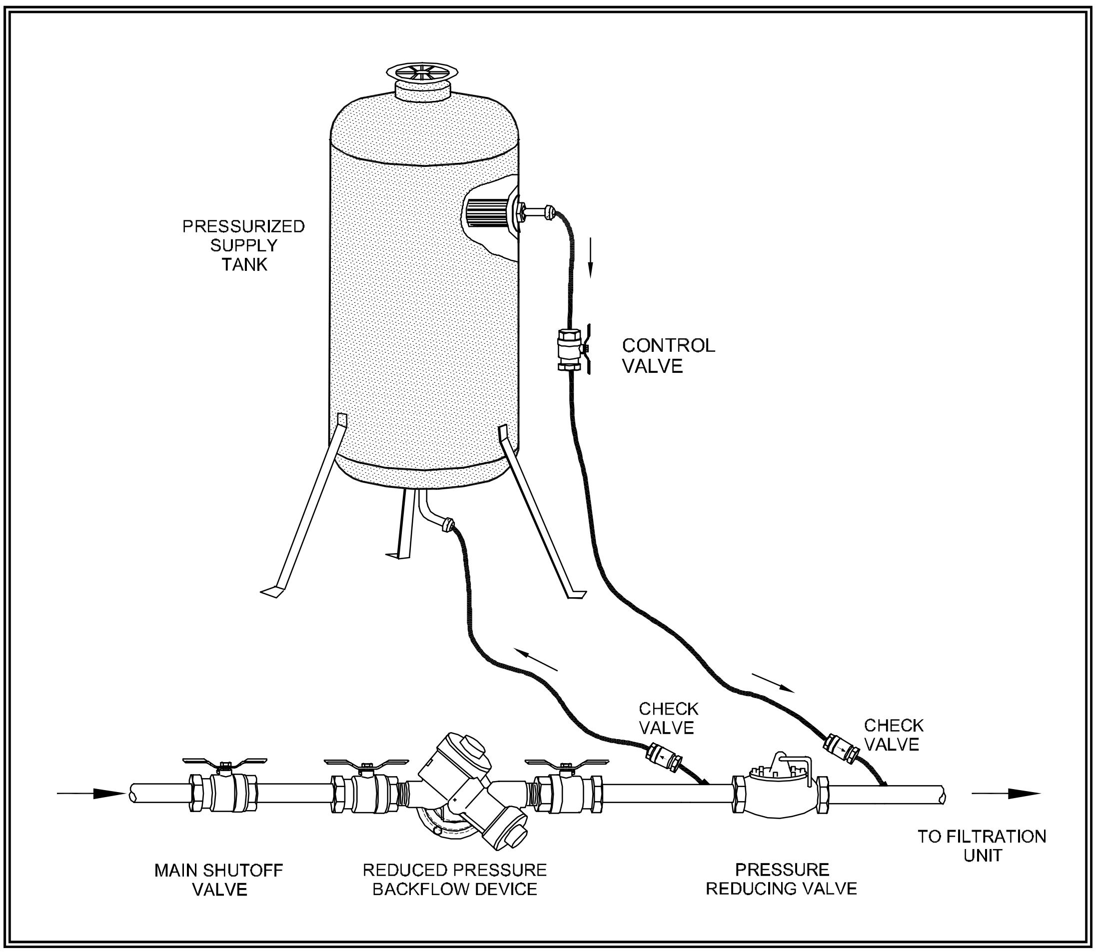

Figure 6.2 **Pressure Differential Injection System**

Venturi Principle Injection System

Venturi injectors operate by creating a vacuum when water is forced through a constriction. The vacuum sucks the chemical into the irrigation water stream at the point of constriction. Venturi are most commonly installed on a by-pass to a pressure reducing device such as a regulator or a gate valve (see Figure 6.3). To operate effectively, venturi must have a pressure drop of 20-50% of the inlet pressure and are therefore not effective where supply pressures may be low. The primary advantage of a venturi system is the low cost.

The rate of chemical injection is dependent upon the flow rate through the venturi which are affected by the operating pressure, venturi size, construction and any flow constrictions or flow control devices that may be installed on the venturi discharge line. The injection rate can be adjusted by varying the flow through the injector, adjusting the system operating pressure or adjusting the controls on the discharge line. A metering valve on the suction line may also be used to control the injection rate. Once established, the rate of injection will remain constant for a zone. As the chemical is not diluted while it is injected, the concentration of the chemical mix is also constant.

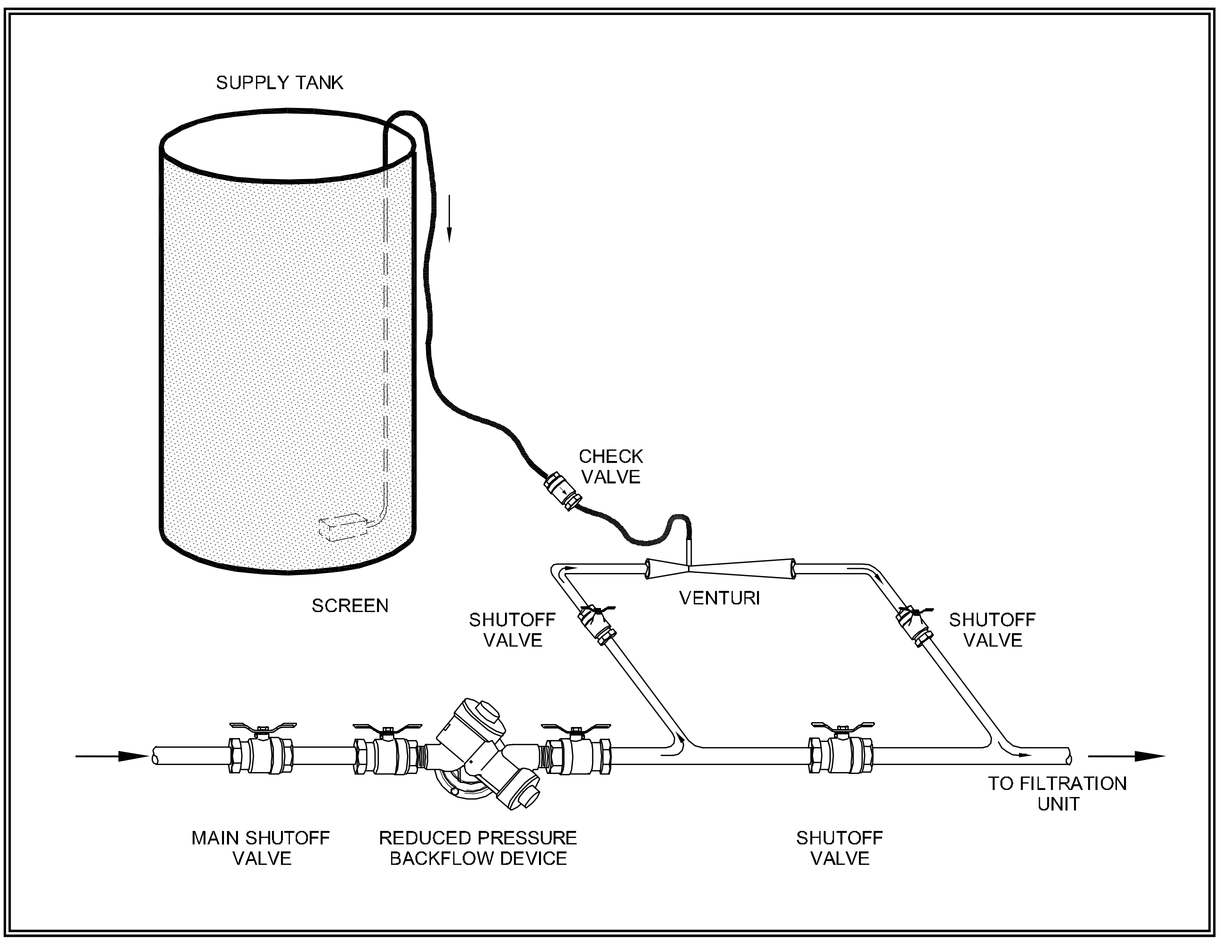

Figure 6.3 **Venturi Injection System**

Table 6.1 provides information on the injection capacities of various size venturi injectors for different operating conditions and flows through the injectors. Specifications from the injector company should be used in making the final selection of an injector.

Table 6.1	Venturi Injector Selection				
Model	Size In/ Out	Pressure Differential	Flow through Injector @ 50 psi (gpm)	Injection Rate	
				L/hr	gal/hr
283	1/2"	26%	0.5	23	6
384	1/2"	25%	2.1	38	10
484	1/2" -3/4"	18%	3.4	64	17
584	3/4"	18%	6.4	95	25
878	1"	16%	12	227	60
1078	1"	16%	17	284	75
1583	1 1/2"	18%	34	680	180
2081	2"	18%	101	1890	500
384-x	1/2"	50%	2.1	132	35
885-x	1"	32%	12	530	140
1585-x	1 1/2"	35%	36	1325	350
2083-B	2"	67%	29	4275	1130

From Mazzei Injector Corporation

6.3 ACTIVE INJECTORS

Active injectors use an external energy source or a mechanical moving part to create pressures exceeding the irrigation mainline pressure to inject the chemical. The main types of active injectors are pumps or compressor systems.

Injection Pumps

Injection or metering pumps use gear, rotary, piston, or diaphragm to develop the pressures exceeding the irrigation system pressure to inject the chemical. Injection pumps, within the minimum to maximum operating range, should have a delivery accuracy of plus or minus one percent. The pumps should be easily adjusted for different injection rates and be constructed of non-corrosive materials.

Injection pumps are available in constant rate and constant ratio feeder systems. A constant rate system will deliver a constant injection rate irrespective of the irrigation system flow rate. Constant ratio feeders inject chemicals at a rate determined by the flow of the irrigation system. The concentration of chemical in the irrigation water therefore remains the same.

The injection pump selected should have a capacity that is consistent with the application rate of chemicals to be injected. Pumps should not be operated at the maximum or minimum output as pumping accuracy is affected and pump damage could occur. Figure 6.4 shows a metering injection pump.

Diaphragm Pumps

Diaphragm pumps are more expensive than piston injection pumps but offer distinct advantages over other types of injection units.

- They have a small number of moving parts.
- Limited areas of the components are exposed to the chemicals injected. This reduces the potential for corrosion, wear and leakage, lowering maintenance costs and enhancing environmental safety.
- The injection rate is easily adjusted while the pump is operating.

Piston Pumps

Piston pumps are available in single and dual injection heads with a wide range of injection capacities. Piston pumps are most commonly used in situations that require a high injection rate. These pumps have distinct disadvantages for chemigation:

- Piston seals are subject to accelerated wear.
- Calibration of most piston pumps is time consuming. Altering the injection rate requires stopping the pump and altering the stroke length mechanically. The pump must then be restarted and the injection rate checked. Some models offer variable speed drives to adjust injection rates.
- Piston pumps lose suction capabilities proportionally as stroke length of the piston is reduced to pump smaller amounts. It is more efficient and consistent to operate within the middle capacities of the pump.

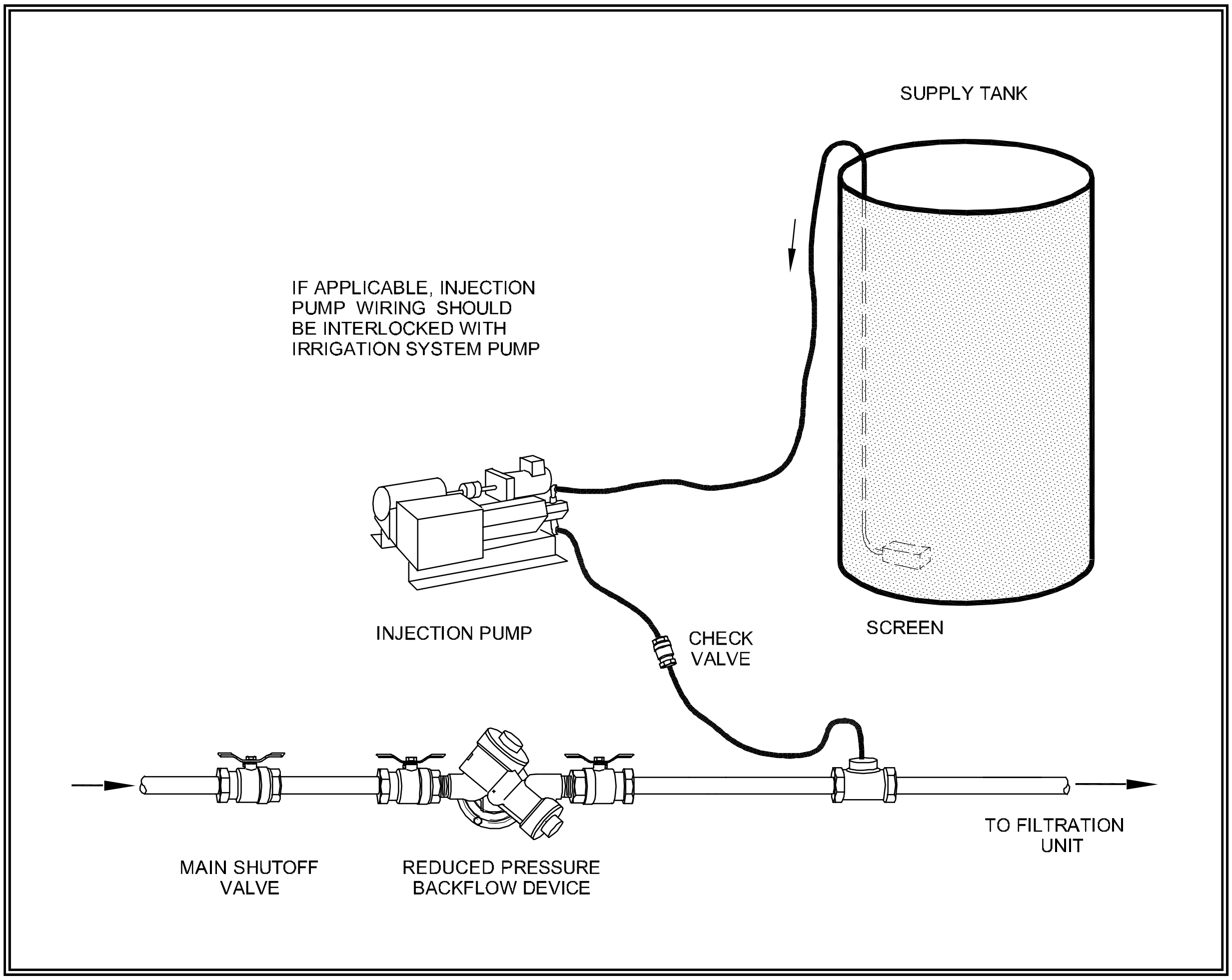

Figure 6.4 **Metering Injection Pump**

Water Powered Injectors

Water powered injectors are considered active injectors although an external energy source is not used. The energy of the pressurized water in the irrigation system is used to drive the injector. Water powered injectors are available in turbine (impeller) or piston drive.

A turbine water driven injector does not expel water but does utilize some irrigation supply pressure to drive the unit. (See Figure 6.5) The irrigation system design and injector selection must consider the additional losses to ensure that adequate pressure is available to operate the system and injector. These types of injectors are available in single and double head models.

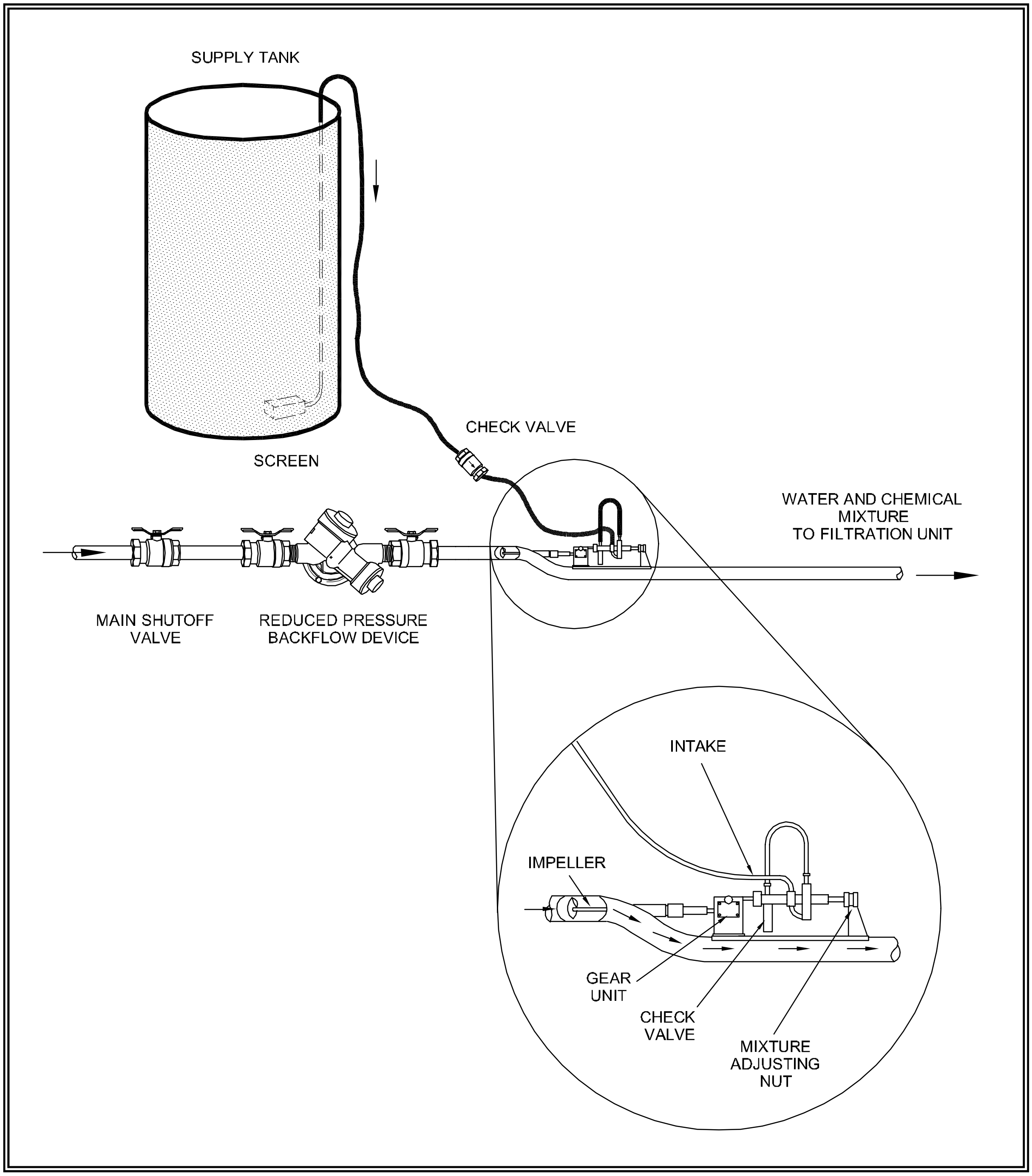

Figure 6.5 **Water Turbine Driven Injector**

Piston operated units use a small amount of the pressurized irrigation water supply to drive the piston. The drive water that is expelled from the piston is usually three times the quantity of the injected solution. The injection rate is set by controlling the amount of water entering the piston drive. Piston drive units do not reduce the irrigation system pressure. Figure 6.6 shows a piston drive injection system.

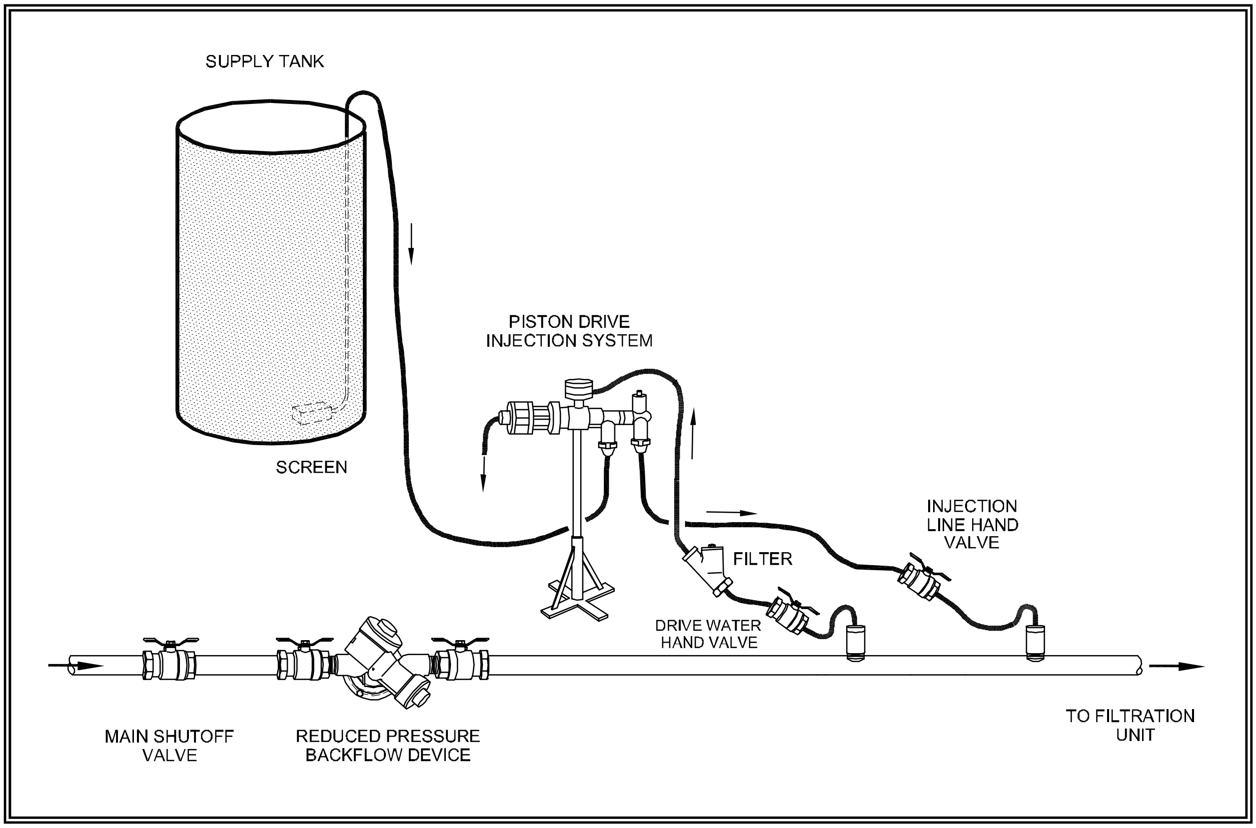

Figure 6.6 **Piston Drive Injection System**

Compressor Injectors

Another form of active injection is to use compressors to pressurize a tank with a diaphragm containing the fertilizer mix. The pressure in the tank is set higher than the irrigation system pressure to allow for chemical flow from the tank into the irrigation system. Control valves on the discharge line are used to control the injection rate from the tank. This system is not commonly used due to the expense of purchasing and linking all the components required. The system does not offer any major advantages over other types of injection systems.

6.4 INJECTOR CALIBRATION

Proper operation of a chemigation system requires calibration of the irrigation and injection system. Chapter 7 covers the calibration of an irrigation system using chemigation in more detail. Procedures for the calibration of an injector are provided here.

It is always a good idea to calibrate your own injection system rather than rely on the manufacturer's specifications. Manufacturer's suggestions may eliminate the need for trial and error but conditions at the site will never be the same as in a factory setting. The injection system should be calibrated with the irrigation system operating under normal conditions, and the injection supply tank located in its permanent position.

Calibration Tubes

A stop watch and graduated cylinder are required to perform the injector calibration. The calibration container should be clear, large enough to hold a volume sufficient for five minutes of injection and calibrated in millilitres or ounces. The calibration container is filled and the injector is allowed to pump from it for a specific period. Alternately, the time required to pump a fixed volume from the container may be measured.

The injector is calibrated by measuring the amount of material pumped from the calibration tube over the time interval measured with the stop watch. This method is superior to pumping into a container as pressure is always maintained against the injection pump.

Although not as accurate as a calibration container, the injection rate can also be found by measuring the amount of chemical solution removed from the supply tank. This method is acceptable for batch fertigation but should not be used for the injection of pesticides or herbicides or for continuous moving irrigation systems.

Venturi, pitot tube or pressure differential injection systems need not be accurately calibrated if these injectors are only used for batch type fertilizer injection. However, the injection of herbicides or pesticides will require accurate knowledge of the injection rate.

7 Calculating Injection Rates

Proper operation of a chemigation system requires appropriate equipment and accurate calculations to determine the correct application rate. This section provides detail on calibrating chemigation systems and calculating system injection rates.

7.1 DETERMINING A METHOD OF CALCULATING INJECTION RATES

There are four different methods that can be used to determine how much chemical must be added by the injection system. Usually it is not practical to adjust chemigation rates by adjusting the injection rate. With venturi, for instance, the injection rate will be fixed by the operating pressures of the irrigation system. With variable speed metering pumps, it will be necessary to reset injection rates or solution concentrations to adjust for unequal sized zones. It is therefore more practical to use alternative procedures for controlling application rates. Four different methods could be used depending on the type of chemical, injector, type of irrigation system, zone size and number of zones.

1. **Weight Method**

   Weigh out the desired weight of material to be applied, dissolve in a convenient amount of water, and inject until it has all been applied. Knowledge of the injection rate will be required to ensure that concentration in the irrigation lines is not too strong and that the time for injection is not too long.

2. **Volume Method**

   Similar to the weight method except that concentration of the liquid solution must be known to calculate how much volume to apply.

3. **Injection Rate Method**

   This procedure is explained in the section 7.2

4. **Injection Time Method**

   The time required to inject the amount of chemical is calculated from the injection rate and solution concentration using the same equation as for the injection rate method shown in section 7.2.

7.2 CALIBRATING AN INJECTION PUMPING SYSTEM

Calibration of a chemigation system involves the following basic steps.

1. Determine the area to be treated or the number of plants to be treated with a trickle irrigation system.

2. Determine the amount of chemical to be applied per hectare or per plant.

3. Calculate the total amount of chemical to be applied.

4. Determine the length of injection time in hours. Factors that will influence this are the length of the irrigation set time, irrigation system application rate, transit time from the injection point to the target area and the amount of chemical to be applied.

5. Select the chemical composition to be used and mixture concentration.

6. Set the injection flow rate on the injector.

The injection rate may be predetermined by the capacity of the injector or the flow rate of the irrigation system. The desired injection rate can also be calculated by using the following formula if all of the parameters are known.

$$\mathbf{Ic} = \frac{\mathbf{Qc \times A}}{\mathbf{C \times T}}$$

where:

Ic = Chemical injection rate (L/min)

Qc = Quantity of chemical to be applied to target area (kg/ha)

A = area (ha)

C = concentration of injected solution (kg/L)

T = injection duration (min)

The method of calibrating chemigation systems using different irrigation systems and chemicals is best exemplified through the following examples. Consideration must be given to batch vs continuous injection and the target area effectively covered by the irrigation system.

7.3 BATCH CHEMIGATION EXAMPLES

Irrigation systems such as wheellines, handlines, solid set sprinklers and trickle operate in a batch mode. These systems irrigate a block of land at a constant rate for a fixed period. Batch chemicals can therefore be mixed and applied to these blocks during irrigation.

The amount to be applied is easily determined for a batch application process. The timing of application of a batch system is most critical if the chemical is to be applied to a specific area of the plant's root zone. This is determined by the type of chemical used and the duration of application.

Example 1 Solid Set Sprinkler - Fertilizer Application

Solid set systems irrigate blocks of land controlled by a single valve. The following example provides the calibration sequence for a solid set sprinkler system.

The irrigation system has the following particulars:

- 5/32" x 3/32" nozzle operating at 45 psi
- gpm flow rate per sprinkler
- 90 ft wetted diameter
- 45 ft x 55 ft spacing
- 20 sprinklers operating in the zone
- zone flow rate is 130 gpm
- irrigation set time is 12 hours

Calcium nitrate fertilizer is to be used to apply 50 kg of nitrogen per hectare to a mature orchard crop on a sandy loam soil. The moisture content of the soil is at 25% of the Available Water Storage Capacity. The nitrogen is to be applied to a depth of 300 mm (12 in).

1. Area to be treated.

For a sprinkler system the area to be treated is calculated by using the sprinkler spacing and number of sprinklers. Water application will occur outside this calculated area but it is expected that the same amount will be returned to the target area from the next set.

$$\textbf{Treated area} = \frac{\textbf{no. of sprinklers x sprinkler spacing}}{\textbf{43,560 ft}^2\textbf{ / acre}}$$

$$\text{Treated area} = \frac{20 \times 45 \times 55}{43{,}560}$$

$$= 1.14 \text{ acres}$$

$$= 0.46 \text{ hectares}$$

2. Amount of chemical to be applied per hectare

From Table 5.1 the following information can be obtained on Calcium Nitrate.

- 15.5% N
- solubility - 180 g / 100 g H_2O
  - 1.8 kg/L (this value is interpreted from the table using a temperature of 20^oC)
- $CaCO_3$ equivalency is -20

Calcium nitrate will not acidify the soil as a negative amount of calcium carbonate is required to neutralize the acidic effect.

To apply 50 kg of nitrogen per hectare the weight of Calcium Nitrate fertilizer will be:

$$\mathbf{Qc} = \frac{\textbf{desired amount of N / Ha}}{\textbf{percentage N in fertilizer}}$$

$$= \frac{50}{0.155}$$

$$= 323 \text{ kg of calcium nitrate / hectare}$$

3. Total amount of chemical to be applied

$$\textbf{Amount applied} = \textbf{rate per hectare x no. of hectares}$$

$$= 323 \text{ kg/ha x } 0.46 \text{ hectares}$$

$$= 149 \text{ kg}$$

At a solubility rate of 1.8 kg/L the minimum volume of solution will be:

$$\textbf{Solution volume} = \frac{\textbf{total amount to be applied}}{\textbf{solubility rate}}$$

$$= \frac{149 \text{ kg}}{1.8 \text{ kg/L}}$$

$$= 83 \text{ L}$$

A tank capable of 83 liters of chemical storage is required if calcium nitrate is to be used as the nitrogen source. The nutrient mixture concentration can be diluted if the solubility of the calcium nitrate is reduced due to fertilizer coatings. A larger tank will then be required.

4. Length of injection time

An injection time of 1 hour is selected to ensure that the chemical is applied as uniformly as possible. The chemical is to be applied during part of the normal 12 hour set time so there is ample time to inject the product. Step 6 shows the methodology for calculating when the chemical should be applied if a specified depth is desired.

5. Injection Rate

$$Ic = \frac{Qc \times A}{C \times T}$$

where
Ic = chemical injection rate (L/min)
Qc = 323 kg/ha
A = 0.46 ha
C = 1.8 kg/L
T = 60 min

$$Ic = \frac{323 \times 0.46}{1.8 \times 60}$$

$$= 1.38 \text{ L/min}$$

The maximum concentration of injected solution in the irrigation lines selected for this example is 1%. The irrigation system flow rate is 130 gpm or 490 L/min.

The concentration of solution in the irrigation line is:

$$\textbf{Solution concentration} = \frac{\textbf{injection rate}}{\textbf{system flow rate}}$$

$$= \frac{1.38}{490}$$

$$= 0.0028 \text{ or approximately } 0.3\%.$$

For this example, a 1.38 L/min injection rate is well within the 1% fertilizer concentration limit that was set.

6. Depth of Penetration

$$\textbf{Application rate} = \frac{\textbf{96.3 x gpm}}{\textbf{sprinkler spacing}}$$

$$= \frac{96.3 \times 6.5}{45 \text{ ft} \times 55 \text{ ft}}$$

$$= 0.25 \text{ in/hr}$$

Total application = application rate x time

= 0.25 in/hr x 12 hrs

= 3 in applied

Depth of water penetration = total application x (table 3.3 value)
(25% moisture content on sandy loam)

= 3 in x 11 in/ inch applied

= 33 inches

Desired depth of chemical is 12 inches

Amount of irrigation required = $\frac{12}{33}$ inches x 12 hrs

= 4.4 hours of irrigation required after injection begins

The chemical injection must be started 7.6 hours after the irrigation set begins and be completed one hour later. The chemical will then have 4.4 hours to infiltrate into the soil to a depth of 12 inches during a 12 hour irrigation set.

Example 2 Trickle Irrigation System - Granular Fertilizer

Trickle systems irrigate the plant's roots directly and should be designed to irrigate blocks of the same maturity, crop and soil type. For this example, a first year planting of tree fruits requires 15g of phosphorous to be applied. The following parameters are used for this example:

- the orchard is high density with plant spacings of 5 ft and rows spaced 12 ft apart
- the rows are 250 ft long (50 plants per row)
- one zone irrigates 20 rows at one time
- each tree is supplied by two 2 L/hr emitters
- a normal irrigation is approximately 9 hours of operation per day during peak conditions for a mature crop. For a first year crop the operating time is estimated to be 2 hrs per day.

The grower wishes to apply 15 g of actual phosphorus to each plant over the growing season, in 8 equal applications one week apart. **Monoammonium phosphate** will be used as the phosphorus source.

1. Number of plants to be treated

Number of plants = plants per row x number of rows
= 50 x 20
= 1000

2. **Amount of chemical to be applied per application**

From table 5.1 the following information can be obtained on monoammonium phosphate.

- 11% N
- 22% actual P (Note phosphorus fertilizers often provide the amount of phosphorus as P_2O_5. To convert from P_2O_5 to actual P, divide P_20_5 by 2.3)
- solubility - 43 g / 100 g H_2O
  - 0.43 kg/L
- $CaCO_3$ equivalency is 58

Monoammonium phosphate has an acidifying effect on the soil. Liming may be required if this fertilizer is used extensively.

The amount of actual fertilizer to be applied per application is:

$$\textbf{Amount applied} = \frac{\textbf{amount per tree x no. of trees}}{\textbf{no. of applications x \% P in fertilizer}}$$

$$= \frac{15 \text{ g/tree x } 1000 \text{ trees}}{8 \text{ x } 0.22}$$

$$= 8{,}522 \text{ g}$$

$$= 8.5 \text{ kg}$$

3. **Volume of solution**

The minimum volume of solution required to dissolve this amount of fertilizer will be:

$$= \frac{\textbf{total amount to be applied}}{\textbf{solubility rate}}$$

$$= \frac{8.5 \text{ kg}}{0.43 \text{ kg/L}}$$

$$= 19.8 \text{ L}$$

The minimum storage tank size required is therefore 20 L. In this example 30 L is used to dissolve the 8.5 kg of fertilizer.

The solution concentration is therefore 8.5 kg / 30 L = 0.28 kg /L.

4. Injection Rate

All of the chemical is to be injected in 1 hour. The injection rate is therefore 30 L/hr.
The maximum concentration of injected solution into the irrigation lines is selected to be 1%. The flow rate of this zone is:

1000 trees x 4 L/hr/tree = 4000 L/hr

Concentration of chemical in the irrigation lines is:

$$= \frac{\text{injection rate}}{\text{system flow rate}}$$

$$= \frac{30 \text{ L/hr}}{4000 \text{ L/hr}}$$

$$= 0.0075 \text{ or } 0.75\%$$

This injection rate is therefore acceptable.

The amount of nitrogen applied to each tree can also be calculated. The N concentration in the fertilizer is 11% vs 22% for phosphorus. A total of 7.5 g of N is therefore applied to the crop over the 8 applications.

Example 3 Line Source Trickle System - Liquid Fertilizer

A line source trickle system is used to irrigate a strawberry crop. A liquid fertilizer solution is to be used to apply nitrogen and phosphorus to the crop. The following parameters exist for the irrigation system.

- the strawberries are spaced 1 ft apart with rows 4 ft apart
- row lengths are 300 ft (300 plants per row)
- 12" x 60" Bi-wall operating at 12 psi is used to irrigate the crop
- flow rate is 1.55 gpm per 300 ft row
- there are 25 rows irrigated by one zone
- a normal operating time for each zone is approximately 1 hour

The grower wishes to apply a total of 1 g of N and 1.5 g of P to each plant in five equal weekly applications at the beginning of the season. An ammonium polyphosphate solution is to be used.

1. Number of plants to be treated

Number of plants = plants per row x number of rows in one zone
= 300 x 25
= 7500 plants

2. Amount of chemical to be applied per application

In this case a nutrient solution should be selected that closely matches the nutrient application desired.

From table 5.2 the following information can be obtained on ammonium phosphate solutions:

Select an ammonium polyphosphate solution of 10-34-0.

- 10% N
- 34% P_2O_5 To convert to actual P divide by 2.3
- 14.8% P
- density is 1.37 kg/L
  1370 g/L

The amount of fertilizer required to fulfill the minimum nutrient requirement is:

$$\text{Amount of fertilizer} = \frac{\textbf{amount per plant x number of plant}}{\textbf{no. of applications x density of solution x \% nutrient}}$$

$$\text{For N} = \frac{1 \text{ g/L} \times 7{,}500}{5 \times 1370 \text{ g/L} \times 0.10}$$

$$= 10.95 \text{ litres}$$

$$\text{For P} = \frac{1.5 \text{ g} \times 7{,}500}{5 \times 1370 \text{ g/L} \times 0.148}$$

$$= 11.1 \text{ litres}$$

Approximately 11 litres of 10-34-0 solution are required per application.

3. Injection rate

The fertilizer is to be applied during a 20 minute duration half way into the irrigation cycle to allow for proper pressurization of the system and adequate flush time after injection has been completed. The injection rate is therefore:

$$\frac{11 \text{ litres}}{20 \text{ minutes}} \times \frac{60 \text{ minutes}}{\text{hour}} = 33 \text{ litres/hr}$$

The maximum concentration of injected solution in the irrigation lines should not exceed 1%. The flow rate of the zone is:

1.55 gpm / lateral x 25 laterals = 38.75 gpm

(1 U.S. gal = 3.785 litres)

= 8800 L/hr

The concentration of chemical in the irrigation line is:

$$= \frac{\text{injection rate}}{\text{system flow rate}}$$

$$= \frac{33 \text{ L/hr}}{8800 \text{ L/hr}}$$

$$= 0.003754 \text{ or } 0.375\%$$

This injection rate is therefore acceptable.

7.4 CONTINUOUS MOVE CHEMIGATION EXAMPLES

Continuously moving systems include center pivots, travelling guns and linear move irrigation systems.

Example 4 Center Pivot System - Fertilizer Application

In center pivot systems, while the amount of water applied along the lateral is uniform, the rate of application increases with the distance from the pivot point. The injection of chemicals into a moving irrigation system must be matched with the rate of travel. Calibration of the injector to match the pivot travel speed and area covered is essential if effective chemigation is to be achieved with a center pivot system.

To find the rate at which the target area is covered the following factors must be determined:

- circumference of the last tower wheel track
- total acreage to be treated
- travel speed of the last tower

To properly calibrate the system, the travel speed of the center pivot is the most important parameter to be determined. The operation manual may provide some information of system travel speed but this is not accurate enough for chemigation purposes. An accurate travel speed can only be obtained by measuring the time it takes for the outside tower to travel a certain distance. This can be done by:

- marking the end tower's progress with small flags and allowing the system to travel a minimum distance of 20 m.

- operating the system at the same speed and pressure as used during the chemigation application.

- measuring the time between the start of motion of the wheel at one flag and start of motion of the wheel at the next flag with a stop watch.

- measuring the distance travelled by the end tower during this period.

The travel speed should be checked at various locations if terrain varies or if dry and wet conditions exist. An average value should then be used.

The injector pump should also be calibrated accurately for continuous move systems. See section 6.4 for further information on calibrating an injector.

Other considerations with a center pivot chemigation system are:

- The chemical supply tank must have sufficient capacity for the injector to operate continuously for the duration of one complete revolution. The recommended amount of product for the acreage to be covered must be thoroughly mixed into enough water for the injection system to operate continuously for one revolution.

- The mixture in the supply tank should be agitated continuously while injection is taking place to ensure uniformity of concentration.

- The injection equipment must be shut off after one revolution but the irrigation system should continue to operate until the product has been cleared from the system.

- Intermittent operation of the end gun will affect the chemical application rate. If the area calculations assume the end gun is operating continuously then over application will result when it is not. If the area calculations do not include the end gun then under application will result when it does operate. The best and most practical option is not to allow the end gun to operate intermittently. If it does then two chemical injection rates need to be calculated and the adjustments made manually to coincide with the on/off operation of the end gun.

Example

A center pivot system operating on a three cut alfalfa system is to apply 50 kg of N per hectare for each of three applications through the first half of the growing season. The center pivot system has the following parameters:

- length from pivot point to last tower is 1170 ft
- the end boom is 30 ft long
- an end gun with a flow rate of 150 gpm and 150 ft radius is operated continuously
- the pivot operates at 65 psi with a flow rate of 580 gpm
- the pivot travel speed of the end tower has been measured as 5.5 ft/min

Granular ammonium nitrate is to be used as the fertilizer source.

1. **Area to be treated.**

The total irrigated radius of the center pivot system is:

radius = 1170 ft + 30 ft + 150 ft = 1350 ft

Treated area $= \dfrac{\pi \times r^2}{43{,}560}$

$= \dfrac{\pi \times 1350 \text{ ft} \times 1350 \text{ ft}}{43{,}560 \text{ ft}^2/\text{ acre}}$

= 131.5 acres

= 53 hectares

2. **Amount of chemical to be applied per hectare**

From table 5.1 the following information can be obtained on granular ammonium nitrate.

- 34% N
- solubility - 170 g / 100 g H_2O at 15^0C (interpreted from table)
  - 1.70 kg/L
- $CaCO_3$ equivalency is 62

Ammonium nitrate will have an acidic effect on the soil.

To apply 50 kg of N per hectare:

$= \dfrac{\textbf{desired amount of N/Ha}}{\textbf{percentage N in fertilizer}}$

$= \dfrac{50}{0.34}$

= 147 kg of ammonium nitrate / hectare

3. **Total amount of chemical to be applied**

= **rate per hectare x hectares**

= 147 kg/Ha x 53 Ha

= 7791 kg

4. Size of chemical storage facility

At a solubility rate of 1.70 kg / L the total amount of solution required is

$$= \frac{\textbf{total amount to be applied}}{\textbf{solubility rate}}$$

$$= \frac{7791 \text{ kg}}{1.70 \text{ kg/L}}$$

$$= 4583 \text{ litres}$$

A tank capable of adequately storing 5000 litres of solution should be used. A 5000 litre solution would have a concentration of 1.56 kg/L.

5. Circumference of last wheel track

$$\textbf{Circumference} = \mathbf{2 \times \pi \times r}$$

$$= 2 \times \pi \times 1170 \text{ ft}$$

$$= 7351 \text{ ft}$$

6. Revolution time

The revolution time is determined from the circumference and travel speed. The travel speed has been measured at 5.5 ft/min.

$$\textbf{Time / revolution} = \frac{\textbf{circumference}}{\textbf{ft/min}}$$

$$= \frac{7351 \text{ ft}}{5.5 \text{ ft/min}}$$

$$= 1336 \text{ min}$$

7. Injection rate

The injection rate can be calculated a number of different ways all yielding the same result.

$$\textbf{Injection rate} = \frac{\textbf{litres to be injected}}{\textbf{time}}$$

$$= \frac{5000 \text{ L}}{1336 \text{ min}}$$

$$= 3.74 \text{ L/min}$$

Another method is to use the formula at the beginning of this section.

$$Ic = \frac{Qc \times A}{C \times T}$$

Qc = 147 kg/ha

A = 53 ha

C = 1.70 kg/L

T = 1336 min

$$Ic = \frac{147 \text{ kg/ha} \times 53 \text{ ha}}{1.56 \text{ kg/L} \times 1336 \text{ min}}$$

= 3.74 L/min

= 224 L/hr

Example 5 Center Pivot System - Pesticide Application

If premixed fertilizer solutions or pesticides are to be applied through a center pivot system then the injection rate may be more easily determined by calculating the hectares treated per minute. If the parameters in example 4 are used to apply 2500 ml/ha then the injection rate is calculated as follows:

$$\textbf{Hectares treated /min} = \frac{\textbf{hectares treated}}{\textbf{revolution time}}$$

$$= \frac{53 \text{ hectares}}{1336 \text{ min}}$$

= 0.04 ha/min

Injection rate = Ml/ha x area treated/ min

= 2500 Ml/ ha x 0.04 ha/min

= 100 mL/min

= 6.0 L/hr

The concentration of chemical in the irrigation line should be less than 1%. For most center pivot systems the flow rate of the system is high enough that meeting this criteria is generally not a problem.

Example 6 Travelling Gun System - Fertilizer Application

Note: A travelling gun system is very susceptible to wind drift. Chemigation through a travelling gun system should not be practiced during even the slightest wind condition.

As with all travelling systems, calibration of the injector to match the gun travel speed and area covered is essential if effective chemigation is to be achieved. Travelling guns must be equipped with accurate speed control to ensure a constant retraction speed regardless of drum diameter.

To find the rate at which the target area is covered the following factors must be determined:

- acreage covered during each run of the machine
- travel speed of the cart

The travel speed of the travelling gun is the most important aspect of properly calibrating the injection system. An accurate travel speed can only be obtained by measuring the time it takes the cart to move a certain distance. The following methodology should be used:

- Mark the cart location in the field with a flag and position another flag a distance of 10 m away along the operating lane.

- Operate the system at the same speed and operating pressure as will be used during the chemigation application.

- Measure the time it takes the cart to move the 10 m distance with a stop watch.

The travel speed should be measured at a number of locations along the run to ensure that an average speed can be determined.

The injector pump should also be calibrated accurately for continuous move systems. See section 6.4 for further information on calibrating an injector.

Other considerations with a travelling gun chemigation system are:

- The chemical supply tank must have sufficient capacity for the injector to operate continuously for the duration of one complete set. The recommended amount of product for the acreage to be covered must be thoroughly mixed into enough water for the injection system to operate continuously for one irrigation set.

- The mixture in the supply tank should be agitated continuously while injection is taking place to ensure uniformity of concentration.

- The injection equipment must be shut off after the irrigation set is completed but the irrigation system should continue to operate until the product has been cleared from the system.

Example

A travelling gun system is operating on a corn field. The farmer wishes to apply 50 kg of N per hectare in one application in the early spring. The travelling gun system has the following parameters:

- the field size is 1200 ft x 1320 ft
- the travelling gun must cover 1320 ft
- the system is using a 1.0" taper bore nozzle operating at 75 psi
- the gun flow rate is 250 gpm with a wetted diameter of 345 ft
- the lane spacing is 200 ft
- the irrigation design travel speed of the system is 56 ft/hr, however on site measurement indicates the actual travel speed is 50 ft/hr

An ammonium nitrate solution that contains 20% N by weight is to be used.

1. Area to be treated.

The area to be treated per irrigation set is:

$$\textbf{Treated area} = \frac{\textbf{lane spacing x length of run}}{\textbf{43560 ft}^2\textbf{ / acre}}$$

$$= \frac{200\text{ ft x }1320\text{ ft}}{43560\text{ ft}^2\text{ / acre}}$$

$$= 6.06\text{ acres}$$

$$= 2.45\text{ hectares}$$

2. Amount of chemical to be applied per hectare

From table 5.2 the following information can be obtained on ammonium nitrate solution.

- 20% N
- density is 1.27 kg/L

$$\textbf{Amount applied per hectare} = \frac{\textbf{desired amount of N / Ha}}{\textbf{\% N in solution x density}}$$

$$= \frac{50\text{ kg/ha}}{0.20\text{ x }1.27\text{ kg/L}}$$

$$= 197\text{ L ammonium nitrate solution / ha}$$

3. **Total amount of chemical applied**

= **rate per hectare x hectares**

= 197 L / ha x 2.45 ha

= 482 L

The storage tank must be a capable of storing at least 500 litres.

4. **Length of run**

The irrigation system must cover a total length of 1320 ft. The length of hose that must be reeled out to cover this distance is:

hose length = **lane length - radius of gun**

= 1320 ft - 173 ft

= 1148 ft

5. **Travel time**

Travel time = $\frac{\textbf{hose length}}{\text{travel speed}}$

= $\frac{1148 \text{ ft}}{50 \text{ ft/hr}}$

= 23 hrs

6. **Injection Rate**

Injection rate = $\frac{\textbf{litres to be injected}}{\textbf{travel time}}$

= $\frac{482 \text{ L}}{23 \text{ hrs}}$

= 21 L/hr

The concentration of chemical in the irrigation line should be less than 1%. For most travelling gun systems the flow rate of the gun is high enough that meeting this criteria is generally not a problem.

APPENDIX A

CROSS CONNECTION CONTROL BY-LAW

The following bylaw or one similar has been accepted by most water authorities supplying irrigation water in the British Columbia interior. Copies of this bylaw have been circulated to most water purveyors.

1. In this Bylaw:

   (a) ***"Water Authority"*** includes any municipality, regional district, improvement district, irrigation district, water users community, water works district, water utility and any other corporation that have the authority to supply water for the purposes of irrigation, domestic or other uses.

   (b) ***"Trustee"*** means the Trustee of the Water Authority or any person authorized by the Trustee to act on their behalf.

   (c) ***"Private Water System"*** means a water system privately owned or operated for the delivery or distribution of water and includes any domestic use, irrigation system, greenhouse and hydroponic system, and any other use of water supplied by the Water Authority's waterworks system.

   (d) ***"Certified Tester"*** means a person holding a valid certificate from the British Columbia Water and Waste Association for the purpose of testing and servicing all types of backflow prevention devices.

   (e) ***"Person"*** includes a corporation, partnership or party and the personal or other legal representative of a person to whom the context can apply according to law and the singular includes the plural and the masculine includes the feminine.

   (f) ***"Cross Connection"*** means any physical arrangement whereby the Water Authority's water supply is connected, directly or indirectly, with any non-potable or unapproved private water supply system, sewer, drain, conduit, well, pool, storage reservoir, plumbing fixture, or any other device which contains, or may contain, contaminated water, liquid, gases, sewage, or other waste, of unknown or unsafe quality which may be capable of imparting contamination to the public water supply as a result of backflow.

   (g) ***"Backflow"*** means the reversal of flow from the private water system to the Water Authority's waterworks system.

   (h) ***"Potable Water"*** means water that is fit for human consumption as defined in the British Columbia Drinking Water Regulation.

2. Subject to the provisions of Sections 3 and 4 of this Bylaw:

   No person shall create a cross connection by connecting, causing to be connected, or allowing to remain connected to the Water Authority's waterworks system any device, piping, fixture, fitting, container, appliance or any other chattel or thing which may under any circumstances allow non-potable water, waste water or any chemical, liquid or other substance to enter the Water Authority's waterworks system.

3. No owner or operator of a Private Water System connected to the Water Authority's waterworks system shall permit the creation of a cross connection or the introduction of any chemicals or foreign matter whatsoever into the Private Water System except upon strict compliance with the following:

   (a) The owner or operator of any Private Water System wishing to inject or introduce chemicals or foreign material into the water system must notify the Water Authority in writing of their intentions to do so.

   (b) The owner or operator of the Private Water System shall install a type of backflow prevention assembly approved by the Water Authority on the water system at the location of the service connection from the Water Authority or another location approved by the Trustee.

   (c) The backflow prevention assembly shall be installed in accordance with the current edition of ***"Accepted Procedure and Practice in Cross Connection Control"*** prepared by the Cross Connection Control Committee, Pacific Northwest Section, American Waterworks Association or as otherwise directed by the Water Authority.

   (d) The backflow prevention assembly shall be a device approved by the University of Southern California Foundation for Cross Connection Control and Hydraulic Research and the Canadian Standards Association.

   (e) The owner or operator of a Private Water System shall have the backflow prevention assembly inspected once in each twelve (12) month period basis by a Certified Tester to ensure that it is an approved assembly, installed correctly and in proper operating condition. If the assembly is found to be faulty, it must be fixed and retested. A copy of the test report shall be provided to the Water Authority within thirty (30) days of completion of the test.

   (f) The owner or operator will provide to the Water Authority within 30 days of initial installation of the backflow prevention assembly a certificate from a certified technician conforming:

      i) the date of installation of the backflow prevention assembly,

      ii) the type, model and size of backflow prevention assembly installed,

      iii) that it is an approved assembly installed correctly and in proper operating condition.

4. The operator of a Private Water System for agricultural purposes where a cross connection exists

between the Water Works System of the Water Authority and the Private Water System shall in addition to the general provisions of Section 3 also comply with the following:

(a) An approved reduced pressure backflow prevention device (RPBD) shall be used whenever fertilizers, chemicals or any other substance deleterious to health are introduced to a private water system.

(b) Prior to commencement of operation of the Private Water System in each irrigation season, the owner or operator of the Private Water System shall have the backflow prevention device inspected by a Certified Tester to ensure that it is an approved assembly, installed correctly and in proper operating condition. A copy of the test report shall be provided to the Water Authority within thirty (30) days of completion of the test and prior to operation of the chemical injection system.

(c) It is the responsibility of the owner or operator to ensure that chemicals are registered for the application method being employed and to operate the irrigation and chemical injection system in accordance with the procedures outlined in ***"Chemigation Guidelines for British Columbia",*** prepared by the B.C. Ministry of Agriculture, Fisheries and Food.

(d) The owner or operator assumes responsibility for the operation of the irrigation and injection system and shall ensure that proper backflow prevention procedures are used at the connection to the Water Authority's water works system.

(e) The owner or operator of any sprayer tank filling station shall maintain a minimum air gap of 30 cm between the end of the filler hose and the top of the sprayer tank. If this air gap cannot be maintained or if in the opinion of the Trustee the sprayer filling station is constructed or operated in a manner that constitutes a cross connection with the Water Authority's waterworks system, the provisions of paragraph 6 shall apply.

5. The Water Authority shall be entitled, at its determination to:

(a) inspect the Private Water System located on private property;

(b) impose minimum standards which must be met and satisfied relating to the type of backflow preventer and the installation and maintenance of the same;

(c) inspect the type of backflow preventer and the installation and state of maintenance and repair of the same.

6. Where any condition is found to exist which, in the opinion of the Trustee constitutes a cross connection with the Water Authority's waterworks system, the Trustee shall shut off the water supply service(s) to the property and notify the property owner that an approved backflow prevention assembly(s) shall be properly installed and tested prior to the water service(s) being turned on. If, in the sole opinion of the Trustee, a health hazard does not presently exist, the Trustee may give notice to the property owner to correct the cross connection within a specified period.

7. Any person whose water has been turned off pursuant to this Bylaw shall not have the water from the Water Authority turned on until such time as:

   (a) all of the provisions of this bylaw have been complied with

   (b) the said person pays to the Water Authority a turn on fee of one hundred dollars ($100) and

   (b) the Water Authority has turned on the service.

8. Any person who disobeys or fails to comply with any provision of this Bylaw shall be guilty of an offence and liable on summary conviction to a fine not exceeding Two Thousand Dollars ($2,000) or to imprisonment not exceeding six (6) months, or both, and if the offence is of a continuing nature, to a fine not exceeding Five Hundred Dollars ($500) for each day the offence is continued.

GLOSSARY

Adsorption	Adhesion in an extremely thin layer of molecules to the surfaces of solid bodies or liquids in which they are in contact.
Application Efficiency	A ratio of the net amount of water applied to the gross amount delivered by the irrigation system.
Application Rate	The rate at which irrigation water is applied to the soil in inches per hour.
Application Uniformity	A measurement of the variance of water application.
Availability Coefficient	The maximum fraction of available water storage capacity to be removed before irrigation is required.
Available Water Storage Capacity (AWSC)	The amount of soil water retained between field capacity and the permanent wilting point.
Backflow	A reversal of the normal direction of flow.
Backflow preventer	A device or method that prevents backflow of water in a pipeline.
Backpressure	An occurrence where the irrigation system pressure exceeds the supply pressure of the water purveyor's system.
Backsiphonage	Backflow caused by atmospheric pressure.
Cation	A positively charged ion.
Coefficient of Uniformity	The percentage of deviation from the average application of water from an irrigation system.
Effective Rooting Depth	That depth in the soil above which the roots obtain 90% or more of their water between irrigations.
Effective Soil Water Storage Capacity	The amount of water stored in the soil that is available for crop use.

Evapotranspiration (ET)	The total amount of water transpired by plants and evaporated from the soil surface.
Hydraulic Gradient	The friction loss that corresponds to water flowing through a section of pipeline, fitting, valve or fixture.
Ion	An electrically charged particle on the atomic or molecular scale.
Irrigation Interval	The number of days between the start of an irrigation at any one setting and the start of the next irrigation at the same setting.
Maximum Soil Water Deficit	The maximum amount of water allowed to be removed from the soil before irrigation is required.
Total Dynamic Head	The energy measured in feet imparted by the pump, and is equal to the sum of static lift, friction head, static discharge head and pressure head.
Zone	A portion of an irrigation system that is controlled by one valve.

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