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Design and Installation of Microirrigation Systems

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Design and Installation of Microirrigation Systems

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1 Purpose and scope

1.1 The purpose of this Engineering Practice is to establish minimum recommendations for the design, installation and performance of microirrigation systems: including trickle, drip, subsurface, bubbler and spray irrigation systems. This Engineering Practice should encourage sound system design and operation and enhance communication among involved personnel.

1.2 Provisions of this Engineering Practice are primarily those that affect the adequacy and uniformity of water application, filtration requirements, water treatment, and water amendments.

2 Definitions

2.1 chemical water treatment: Chemical treatment of the water to make it acceptable for use in microirrigation systems. This may include acids, fungicides and bactericides used to prevent emitter clogging or used for pH adjustment.

2.2 control station: The control station may include facilities for water measurement, filtration, treatment, addition of amendments, flow and pressure control, timing of application and backflow prevention.

2.3 crop area: The field surface area allocated to each plant. In tree crops the tree crop area is the spacing multiplied by the row spacing.

2.4 design area: The specific land area which is to be irrigated by the microirrigation system.

2.5 design emission uniformity: An estimate of the uniformity of emitter discharge rates throughout the system, as described by the equation in paragraph 3.5.2.

2.6 emitters: The devices used to control the discharge from the lateral lines at discrete or continuous points.

2.6.1 emission point: Point where the water is discharged from an emitter.

2.6.2 line-source emitters: Water is discharged from closely spaced perforations, emitters or a porous wall along the lateral line.

2.6.3 point-source emitters: Water is discharged from emission points that are individually and relatively widely spaced, usually over 1 m (3.3 ft). Multiple-outlet emitters discharge water at two or more emission points.

2.7 emitter discharge rate: The discharge rate at a given operating pressure from an individual point-source emitter expressed as a volume per unit time or from a unit length of line-source emitter expressed as a volume per unit length per unit time.

2.8 emitter operating pressure: The average operating pressure of the emitters within any simultaneously operated portion of the system.

2.9 evapotranspiration: The combined effects of evaporation from the soil and plant surfaces and transpiration from plants. Peak evapotranspiration is the maximum rate of daily evapotranspiration.

2.10 filtration system: The assembly of independently controlled physical components used to remove suspended solids from irrigation water. This may include both pressure and gravity-type devices and such specific units as settling basins or reservoirs, screens, media beds and centrifugal force units.

2.11 lateral: The water delivery pipeline that supplies water to the emitters from the manifold pipelines.

2.12 main and submain: The water delivery pipelines that supply water from the control station to the manifolds.

2.13 manifold: The water delivery pipeline that supplies water from the submain or main to the laterals.

2.14 manufacturer's coefficient of variation *(C_v)*: This is a measure of the variability of discharge of a random sample of a given make, model and size of emitter, as produced by the manufacturer and before any field operation or aging has taken place.

$$C_v = \frac{s}{\bar{x}}$$

where

$\tilde{x}$ = the mean discharge of emitters in the sample
s = the standard deviation of the discharge of the emitters in the sample

$$s = \left[\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1} \right]^{1/2}$$

where

x_i = the discharge of an emitter
n = the number of emitters in the sample

If a line-source emitter is used, the individual discharges from holes on a one-meter or other specified length of emitter tape are used. This term can also be used to describe the variability in the downstream pressure from pressure control valves or the variability in discharge from flow control valves or orifices.

2.15 microirrigation: The frequent application of small quantities of water on or below the soil surface as drops, tiny streams or miniature spray through emitters or applicators placed along a water delivery line. Microirrigation encompasses a number of methods or concepts; such as bubbler, drip, trickle, mist or spray and subsurface irrigation.

2.15.1 bubbler irrigation: The application of water to the soil surface as a small stream or fountain, where the discharge rates for point-source bubbler emitters are greater than for drip or subsurface emitters but generally less than 225 L/h (60 gal/h). Because the emitter discharge rate normally exceeds the infiltration rate of the soil, a small basin is usually required to contain or control the water.

2.15.2 drip and trickle irrigation: The application of water to the soil surface as drops or tiny streams through emitters. Often the terms drip and trickle irrigation are considered synonymous. For trickle and drip irrigation, discharge rates for point-source emitters are generally less than 8 L/h (2 gal/h) for single-outlet emitters, and discharge rates for line-source emitters are generally less than 12 L/h, per meter (1 gal/h per foot) of lateral.

2.15.3 spray irrigation: The application of water by a small spray or mist to the soil surface, where travel through the air becomes instrumental in the distribution of water. Discharge rates for point-source spray emitters are generally lower than 175 L/h (45 gal/h).

2.15.4 subsurface irrigation: The application of water below the soil surface through emitters, with discharge rates generally in the same range as drip irrigation. This method of water application is different from and not to be confused with the method where the root zone is irrigated by water table control, herein referred to as subirrigation.

2.16 microirrigation systems: The physical components required to apply water by microirrigation. System components that may be required include the emitters, lateral lines, manifold lines, main and submain lines, filter, chemical injectors, flow control station and other necessary items.

2.17 peak daily irrigation water requirement: The net quantity of water needed to meet the peak daily evapotranspiration rate occurring during the growing season expressed in mm/day (in./day).

2.18 percent area wetted: The area wetted as a percentage of the total crop area.

2.19 pumping station: The pump or pumps that provide water and pressure to the system, together with all necessary appurtenances such as base, sump, screens, valves, motor controls, motor protection devices, fences and shelters.

2.20 subunit: The main manifold and lateral pipelines which operate simultaneously and have independent flow control.

2.21 system operating pressure: The average operating pressure downstream from the pumping and control station where the main lines begin.

2.22 water amendment: The fertilizer, herbicide, insecticide or other material added to the water for the enhancement of crop production or as a chemical water treatment to reduce emitter clogging.

2.23 wetted area: The average irrigated soil area in a horizontal plane located at or below the emitter.

3 Design, installation, and performance

3.1 System capacity. Microirrigation systems shall have a design capacity adequate to satisfy the peak irrigation water requirement as described in paragraphs 3.1.1 and 3.1.2 of each and all crops to be irrigated within the design area. The capacity shall include an allowance for water losses (evaporation, runoff, deep percolation) that may occur during application periods. The system shall have the capacity to apply a stated amount of water to the design area in a specified net operation period. The system should have a minimum design capacity sufficient to deliver the peak daily irrigation water requirements in about 90% of the time available or not more than 22 h of operation per day. If a system is designed with a capacity less than the peak daily irrigation water requirement, the design capacity shall be stated in writing.

3.1.1 Design according to peak irrigation requirement. Where irrigation provides all or part of the water to the crop, the system shall have the capacity to meet the peak daily irrigation requirements of all crops irrigated within the design area. Unless field research with microirrigation systems is available, peak daily irrigation water requirements for crops determined with conventional irrigation systems should be used to determine system capacity.

3.1.2 Special cases. If specified by the user (e.g., economic considerations, especially in areas of frequent rainfall) and/or for special uses, the system may be designed with a capacity to apply a required volume of water, which is less than peak, to a design area in a specified net operating period.

3.2 Emitter discharge rate. The following conditions shall be met:

3.2.1 For drip, subsurface, and spray irrigation, the emitter discharge rate should not create runoff within the immediate application area. Small depressional ponds may develop beneath or above an emitter, but channelization to a furrow or other nearby low-lying area should be avoided. In fields with varying soil types, this criterion shall apply to the soil with the lowest infiltration rate unless it is less than 15% of the area irrigated.

3.2.2 For bubbler irrigation, a basin beneath the plant canopy will be required for water control. Applications shall generally be confined to the basin area.

3.2.3 Where natural precipitation and/or stored soil water is not sufficient for germination, special provisions shall be made for germination, or the microirrigation system shall apply water at a rate sufficient to adequately wet the soil to germinate seeds or establish transplants. The depth of a subsurface system for use on annual crops shall be limited by the ability of the system to germinate the seeds, unless it is stated in writing that other provisions will be required for this function.

3.2.4 Proper emitter discharge rate shall be determined and specified. Infiltration rates for different types of local, bare soils may be obtained from responsible agricultural technicians. In the absence of such advice, the proper emitter discharge rate may be estimated on the basis of past experience with similar soil types. In new areas field tests are recommended.

3.3 Number and spacing of emitters. The number and spacing of emitters along the lateral line depend upon the emitter discharge rate, system capacity, soil water-holding capacity, lateral spread of water from the emission points, crop being grown, depth of irrigated root zone, desired water application efficiency and emitter discharge variability. Information on soil water-holding capacity and effective crop rooting depth can usually be obtained from responsible agricultural technicians, or may be estimated on the basis of past experience with similar crops and soil types. The lateral spread of water may also be estimated from past experience, but in new areas field tests are recommended. The area wetted as a percent of the total crop area may range from a low of 20% for widely spaced crops, such as trees for irrigation in high rainfall regions, to a high of over 75% for row crops in low rainfall regions.

3.4 Operating pressure. The design operating pressure shall be in accordance with the recommendations of the manufacturers. The system operating pressure must compensate for pressure losses through system components and field elevation effects.

3.5 Water application uniformity. The water application uniformity (for nonpressure compensating emitters) is affected by the operating pressure, emitter spacing, land slope, pipeline size, emitter discharge rate and emitter discharge variability. The emitter discharge variability is due to pressure and temperature changes, manufacturing variability, aging and clogging.

3.5.1 Emitter manufacturing variability. The expected manufacturer's coefficient of variation *(C_v)* should be available for new emitters operated at a constant temperature and near the design emitter operating pressure. A general guide for classifying C_v values is shown in Table 1.

3.5.2 Design emission uniformity. To estimate design emission uniformity in terms of C_v and pressure variations at the emitter, the following equation is suggested:

$$EU = 100\left[1.0 - \frac{1.27C_v}{\sqrt{n}}\right]\frac{q_m}{q_a}$$

where

EU = the design emission uniformity, %

n = for a point-source emitter on a perennial crop, the number of emitters per plant; for a line-source emitter on an annual or perennial row crop, either the lateral rooting diameter of the plants divided by the same unit length of lateral line used to calculate C_v or 1, which is greater

C_v = the manufacturer's coefficient of variation for point or line-source emitters

q_m = the minimum emitter discharge rate for the minimum pressure in the subunit, L/h (gal/h)

q_a = the average or design emitter discharge rate for the subunit, L/h (gal/h)

Table 2 shows recommended ranges of EU values.

3.5.3 Allowable pressure variations. The following recommendations are made to reduce pressure loss and minimize pipeline sizes in microsystems:

3.5.3.1 Pressure differences at the emitters throughout the system (or block or subunit) should be maintained in a range such that the desired design emission uniformity *(EU)* is obtained. For example, from the equation in paragraph 3.5.2, with an EU of 80%, a C_v of 0.10, and one

Table 1 – Recommended classification of manufacturer's coefficient of variation *(C_v)*

Emitter type	C_v range	Classification
Point-source	<0.05	excellent
	0.05 to 0.07	average
	0.07 to 0.11	marginal
	0.11 to 0.15	poor
	>0.15	unacceptable
Line-source	<0.10	good
	0.10 to 0.20	average
	>0.20	marginal to unacceptable

emitter per plant, the ratio between the minimum and average emitter discharge rate should be no less than 0.92. Since the allowable pressure loss corresponding to the minimum emitter discharge rate will differ depending on the emitter characteristics, the allowable pressure variation should be stated in writing for the specific emitter type and C_v specified.

3.5.3.2 Field shape and slope frequently dictate the most economical lateral direction. Whenever possible, laterals should be laid downslope for slopes of less than 5% if lateral size reduction can be attained. For steeper terrain, lateral lines should be laid along the field contour and pressure compensating emitters should be specified or pressure control devices used along downsloped laterals.

3.5.3.3 Excessive main or submain pressure differences can result in widely varying manifold or lateral takeoff pressures. In some instances, these excessive variations cannot be controlled by main or submain size alone. The only practical alternative is to design for adequate pressure at the lateral lines and properly regulate the pressures at the manifold or lateral lines. This pressure regulation may be accomplished by using automatic pressure regulators, fixed orifice or flow control pipe restrictions, or manually set valves.

3.5.3.4 Pipe sizes for mains and submains should be chosen after considering pipe costs and power costs, while keeping flow velocities within recommended limits for surge control and accounting for the effect on design emission uniformity from the resulting pressure variations. Additional information can be found in American National Standard ANSI/ ASAE S376, Design, Installation and Performance of Underground, Thermoplastic Irrigation Pipelines.

3.6 Filtration systems. A general design recommendation for the water filtration system should include location, size, specification of allowable suspended material sizes, types of filter or filters, and maintenance requirements.

Table 2 – Recommended ranges of design emission uniformity *(EU)*

Emitter type	Spacing (m)	Topography	Slope, %	*EU* range, %
Point source on	>4	uniform	<2	90 to 95
perennial crops		steep or undulating	>2	85 to 90
Point source on	<4	uniform	<2	85 to 90
perennial or semipermanent crops		steep or undulating	>2	80 to 90
Line source on	All	uniform	<2	80 to 90
annual or perennial crops		steep or undulating	>2	70 to 85

3.6.1 Location. A primary filter shall be located after the pump and chemical injection point to remove both large and fine particles from the flow. Secondary filters may be used downstream from the primary filter to remove any particles which may pass through the primary filter during normal or cleaning operations. When secondary filters are used, the size of the openings is usually larger than that of the primary filter to minimize needed attention. Water meters, solenoid-operated valves and final pressure regulators should follow the primary and secondary filters. Lateral-line or in-line filters can be used as additional protection.

3.6.2 Size. Filter flow openings shall be sufficiently small to prevent the passage of unwanted particles into the system. When available, recommendations of the emitter manufacturer shall be used to select the size of the filtration system. In the absence of manufacturer's recommendations, the filter size should be based on the diameter of the emitter opening or the type and size of contaminants to be filtered. The capacity of the filter should be sufficiently large to permit the rated flow without frequent cleaning. Filters that are to be cleaned by hand should not require more than daily maintenance. The maximum permissible head loss across the filter shall be 70 kPa (10 psi) before filter cleaning is required.

3.6.3 Types. Filtration may be accomplished through the use of pressure filters (screen and media) and gravity filters (centrifugal separators, gravity screen filters and settling basins).

3.6.3.1 Pressure screen filters. This filter consists of a screen made of metal, plastic, or synthetic cloth enclosed in a special housing used to limit maximum particle size. The presence of algae in irrigation water tends to cause screen blockage and can considerably reduce filtering capacity. Screens are classified according to the number of openings per inch with standard wire size for each screen size. Most manufacturers recommend 150 to 75 micron (100 to 200 mesh) screens for emitters, but some recommend screens as coarse as 600 microns (30 mesh). Screen flow capacity should not exceed 135 L/s per square meter (200 gpm per square foot) of screen opening.

3.6.3.2 Media filters. Media filters consist of fine gravel and sand of selected sizes placed in pressurized tanks. Media can lose effectiveness with time (due to rounding, etc.) and should be replaced after extended usage. Media filters are not easily plugged by algae and can remove relatively large amounts of suspended solids before cleaning is needed. Cleaning is accomplished by forcing water backwards through the filter (backflushing). Media filters in current use will retain particle sizes in the range of 25 to 200 microns. In general, water flow rates through the filters should be between 10 and 18 L/s per square meter (14 and 26 gpm/ per square foot) of filtration surface area. Media filters should be followed by secondary screen filter or a rinse cycle valve to prevent carryover of contaminants following the backwashing process.

3.6.3.3 Centrifugal separators. Sand separators, hydrocyclones or centrifugal filters remove suspended particles that have a specific gravity greater than water. These filters are ineffective in removing most organic solids. A sand separator can effectively remove a large number of sand particles and may be installed on the suction side of the pump as a prefilter to reduce pump wear.

3.6.3.4 Settling basins. Settling basins, ponds or reservoirs can be used as a form of pre-filtration treatment, but unless covered, the water is exposed to wind-blown contaminants and algae growth. Open reservoirs can be treated with commercially available algicides; however, care must be taken to avoid potential environmental hazards. When used, basins should be sized to limit turbulence and permit a minimum of 15 min for water to travel from the basin inlet to the pumping system intake.

3.6.3.5 Gravity screen filters. Gravity screen filters rely upon gravity instead of water pressure to move water through the screen. Pressure losses across gravity screen filters rarely exceed 7 kPa (1 psi) consequently they can be used in systems where pressure losses must be minimized. They are also effective in removing organic (i.e., algae) as well as inorganic contaminants.

3.7 Flushing system. To assist in keeping sediment buildup at a minimum, automatic or hand flushing of all microirrigation pipelines is recommended on a regular time schedule. Filtration should be effective enough so that flushing of the system is needed no more frequently than once per week.

3.7.1 Location. Valves shall be provided at the ends of mains and submains and provisions made for flushing of lateral lines. All connections and pipeline fittings shall be large enough in diameter to facilitate flushing.

3.7.2 Capacity. A minimum flow velocity of 0.3 m/s (1 ft/s) is needed for flushing of lateral lines. Because only a few lateral lines can be flushed at one time, the flushing system should be adequately valved so that subunits can be flushed independently.

3.8 Chemical water treatment. The need for chemical water treatment depends primarily on the type of microirrigation system used and the composition of the water. Acids and bactericides are both used for prevention of emitter clogging and renovation after clogging occurs.

3.8.1 Acids. The least expensive acid available can be used, usually at a concentration which is sufficient to offset calcium, magnesium or iron carbonate and bicarbonate precipitation. Another method for dealing with water high in bicarbonates is to aerate the water and hold it in a reservoir until equilibrium is reached and the precipitates have settled out.

NOTE: The reduction of water pH may cause harmful effects on crop production if the soil pH is low.

3.8.2 Bactericides. Calcium hypochlorite, sodium hypochlorite, chlorine gas, or other algicides and bactericides can be added continuously or periodically at the control station to inhibit bacterial growth. Registration of these chemicals for use in microirrigation systems may be required. For high pH waters, acids can be injected to adjust pH to increase the bacteria-killing property of the hypochlorites. If hypochlorite and acids are used simultaneously, they shall be injected from separate sources to avoid the possibility of generating lethal chlorine gas. Gas chlorination or hypochlorination is not recommended for water containing more than 0.4 mg/L (0.4 ppm) dissolved iron, since it can lead to the precipitation of iron that may not be filterable and may deposit in pipelines and emitters. The amount of chlorine to be added depends on the chlorine demand and the potential for bacterial emitter clogging. Where bacterial control is needed, enough chlorine should be added to have some measurable amount of free residual chlorine (at least 0.1 mg/L [0.1 ppm]) present at the ends of all lateral lines after a chemical injection period. When continuous or frequent monitoring for chlorine is not possible, it may be prudent to target for 1.0 mg/L (1.0 ppm) free chlorine at the ends of laterals to provide a sufficient safety factor to cover fluctuations in chlorine demand between monitoring times.

3.9 Fertilization system. Microirrigation systems provide a convenient method of supplying nutrient materials to the crop; however, the effects of the nutrient on the system should be considered.

3.9.1 Nitrogen. Ammonium sulfate, ammonium nitrate and urea have been used at low concentrations with no harmful effects on the water or irrigation system. Anhydrous ammonia, aqueous ammonia or ammophos increase pH and can cause chemical precipitation which can clog emitters, particularly with high pH water.

3.9.2 Phosphorus. Commonly used phosphate fertilizers tend to precipitate in irrigation waters with high hydroxyl, calcium and manganese contents. Phosphorous fertilizers can become immobilized in the soil. Phosphoric acid and water-soluble organic phosphorous compounds have been successfully used in microsystems; however, common practice is to apply the phosphorous separately and not through the irrigation system.

3.9.3 Potassium. There are no problems associated with potassium application through microirrigation systems.

3.9.4 Micronutrients. Manganese, zinc, iron, copper, etc., may be applied as soluble salts through the irrigation system. These should each be injected separately and apart from other fertilizers and chemicals to avoid chemical interaction and precipitation in emitters. The effects of improper application amounts on the nutrient balance in the soil should be considered when applying micronutrients.

3.10 Injection system. ASAE Engineering Practice EP409, Safety Devices for Chemigation, specifies required safety devices when injecting chemicals into irrigation systems. The following are some of the more important considerations that shall be considered in the design of a chemical or fertilizer injection system:

3.10.1 Injection method and rate. Fertilizers may be injected by a differential pressure system, venturi injector or by pumping under pressure (pressure injected) into the irrigation water. Other chemicals such as acids, bactericides and chlorine which require a constant concentration rate entering the irrigation water shall be injected by constant rate injection devices only. Chemicals shall be injected into the system before the primary filter. The required rate of chemical injection depends on the initial concentration of chemical and the desired concentration of chemical to be applied during the irrigation. An injector that will operate within a range of injection rates for a number of chemicals may be desired.

3.10.2 Concentration. The concentration of chemicals to be injected in the irrigation water is normally very low, with ranges of 4–100 mg/L (4–100 ppm) for fertilizers and chemicals and 0.5–10 mg/L (0.5–10 ppm) for bactericides. Chemical concentrations should be routinely measured after filters and before main pipelines, and occasionally at the end of the last lateral line, to check if the entire microirrigation system is being treated.

3.10.3 Storage tank capacity. Large, low cost tanks constructed from epoxy-coated metal, plastic or fiberglass are usually practical when injection pumps are used. For a pressure differential injection system, the high pressure rated chemical tank should have enough capacity for a complete application.

3.10.4 Contamination of water supply. When the water supply or pump fails, it may be possible to have reverse flow from the injection or irrigation system. A pressure switch or other means should be used to turn off the injector pump or close a solenoid-operated valve on a differential pressure system so that chemicals cannot be injected when the irrigation pump is not operating. A vacuum-breaker and check valve should be placed between the water supply pump and the injection point to prevent backflow from the pipeline to the water supply. In addition, municipalities may require other backflow prevention valves at connections to municipal water lines to prevent reverse flow, particularly when water is being treated with chemicals or amendments.

3.10.5 Resistance to chemicals. All hardware shall be resistant to reaction with the chemicals being injected.

3.11 Flow monitoring. A flow measuring device shall be installed as part of the control station to aid in scheduling irrigations and monitoring system performance. Flow measurements can indicate if pressure regulation is malfunctioning, excessive leaks exist, emitters are clogging or emitter opening enlargement is occurring. Some flow measuring devices give both the accumulated flow and instantaneous flow rate. Accumulated flow over a specified period of time can be used to determine flow rate if instantaneous readings are not available.

3.12 Safety

3.12.1 The design or operation of the irrigation systems shall prevent the leaking or spraying of water on electrical lines or power units.

3.12.2 Protective devices on chemical injection equipment shall be provided to prevent contamination of the water supply or unplanned discharge of chemicals. A water source should be provided near the chemical tank for washing off chemicals if skin contact occurs. Protective clothing is advisable when handling chemicals.

3.12.3 Pumps and power units shall be set on a firm base and kept in proper alignment. The installation shall comply with American National Standard ANSI/ASAE S318, Safety for Agricultural Equipment.

3.12.4 Wiring and starting equipment for electrically-operated plants shall comply with overload and low voltage protection requirements, and any applicable electrical codes. Electrical installation shall comply with ASAE Standard S397, Electrical Service and Equipment for Irrigation.

3.12.5 Pumps and power units shall be provided with protective devices. Thermostats shall be provided which stop the power units when engine or motor temperatures exceed safety points. If failure of the water supply might cause the pump to lose its prime, the motor or engine shall be properly protected. Chemical and fertilizer injection equipment shall be automatically turned off when the irrigation pump is not operating. Detailed discussions of irrigation safety devices are found in ASAE Engineering Practice EP409, Safety Devices for Chemigation.

Cited Standards:

ANSI/ASAE S318, Safety for Agricultural Equipment
ANSI/ASAE S376, Design, Installation and Performance of Underground, Thermoplastic Irrigation Pipelines
ASAE S397, Electrical Service and Equipment for Irrigation
ASAE EP409, Safety Devices for Chemigation