ENERGY USE FOR MICRO-IRRIGATION

Tom Trout and Jim Gartung[1]

ABSTRACT

Micro-irrigation systems can operate with low pressure. Micro-irrigation emitters require only 7 - 20 psi. Cleaning and delivering the water to the emitters on flat fields typically requires an additional 15 psi. A survey of 312 California micro-irrigation systems showed that 60% of the systems exceed these pressures, and 25% exceed by over 10psi. Pressure could be reduced by an average of 15 psi in 60% of the systems. Pressure was lost at the filter station, in the distribution system, at pressure regulators, in the lateral inlets, and at the emitters. Higher pressure is required to irrigate undulating land. Reducing system pressure by 15 psi in a system could save about $25 per acre per year in electricity costs, and reducing pressure by 15 psi for 60% of the 1.7 million acres of micro-irrigation in California would save 220 Gigawatt-hrs/yr of energy and 90 Megawatts of peak load. It will often be economical to invest more in the system to save pressure and energy costs, but energy-saving changes may decrease system flexibility and simplicity or increase risk of system failures.

INTRODUCTION

Electric energy rates increased by about 30% in California in 2001. Cost for pumping irrigation water now exceeds 12 cents per kw-hr in most cases. Electricity shortages and the high cost of marginal supplies on the spot market induced California to offer irrigators financial incentives to reduce peak electricity demand.

Energy is used to lift water from groundwater wells to the fields and to pressurize the irrigation system. Gravity irrigation methods generally do not require pressurization and are often the lowest energy option. However, gravity systems may be less water use efficient than pressurized systems, resulting in higher well pumping costs. Most sprinkler systems require 50 - 80 psi to operate efficiently. The development of low pressure sprinklers and sprayers, largely in response to energy cost increases in the 1970s, reduced pressure requirements of moving lateral (center pivot, lateral move) sprinkler systems to 30 - 50 psi.

Micro-irrigation is a low pressure alternative to sprinkler systems that can efficiently and uniformly apply irrigation water. Micro-irrigation is used on 1.7 million acres in California and 3 million acres in the U.S. (Irrigation Journal 2001). Drip emitters require 7 - 15 psi, and most micro-sprayers operate well at 15 - 25 psi. However, unlike sprinkler systems which are usually designed for minimal pressure losses between the pump and sprinkler, most micro-irrigation systems use 10 to 30 psi to clean, regulate, and deliver water to the emitters. Thus, pressure requirements are sometimes no lower than with low-pressure sprinkler systems.

Table 1 shows pressure requirements and pressure losses for two types of micro-irrigation

---

[1]Agricultural Engineers, USDA-Agricultural Research Service, San Joaquin Valley Agricultural Sciences Center, 9611 S. Riverbend Ave., Parlier, CA 93648. ttrout@fresno.ars.usda.gov

systems, hose drip systems and micro-spray (jet) systems, based on equipment specifications, design standards, and interviews with micro-irrigation system designers. About 15 psi is needed to clean, control, and deliver water to the emitters for fields on level ground. An additional 7 – 25 psi is required for good emitter operation, depending on the type of emitter. Most filters have minimum pressure requirements for backflushing varying from 20 to 45 psi.

There may be potential to reduce pressure, and thus energy, requirements of micro-irrigation systems through alternative design, equipment selection, or management. A 10 psi pressure reduction would reduce power requirements by about 36 kw-hr/ac.ft. of water pumped or about 220 million kw-hr/yr for California's 1.7 million acres of micro-irrigation.

Energy use in irrigation can be reduced by reducing the amount of water pumped (increased efficiency or deficit irrigation), by increasing the efficiency of the pumping plant, or by reducing the system pressure. For example, for a 100 ac. California orchard that requires 3 ft. of water annually with a well pump with a 100 ft. lift, energy costs can be reduced by about $1800 per year either by increasing the irrigation efficiency from 75% to 85% (ie: reducing the water pumped from 4 to 3.5 ac-ft/ac), by increasing the pumping plant efficiency from 60% to 68%, or by reducing system pressure requirement from 40 to 30 psi. If the water supply is surface water, the irrigation efficiency would need to be increased to 100% or the efficiency of the booster pump to 80% to gain the same savings as reducing system pressure by 10 psi.

The objective of this study is to determine the pressures used with micro-irrigation systems, the sources of pressure loss, and ways to reduce pressure requirements.

Table 1. Pressure losses for micro-irrigation systems.

		Well-designed System*	
System Component	**Range** ***(psi)***	**Microspray** ***(psi)***	**Drip** ***(psi)***
Emitter (microspray, dripper)	7-25	20	15
Lateral hose	1-5	2	2
Manifold	1-5	1	1
Main and Sub-main pipelines	2-10	5	5
Filter (allowable loss)	3-10	5	5
Other losses: (Press. Regulators, Chem. injectors, Control Valves, Flow Meters; Fittings)	1-20	2	2
Total Cumulative	15-75	35	30

* 40 ac. orchard or vineyard on level land with a sand media and screen filter.

METHODS

Several hundred California irrigation systems have been evaluated by mobile irrigation labs using procedures developed by the Irrigation Training and Research Center (Burt et al. 2000). As part of these evaluations, system pressures are measured at several points in the irrigation system. We summarized pressure data from evaluations of 312 micro-irrigation systems in California's San Joaquin Valley and central coast carried out by the Irrigation Training and Research Center[2] (Cal Poly, San Luis Obispo), Kings River Conservation District (Fresno), and USDA-ARS-WMR over the last 5 years. We included only systems that irrigated more than 10 ac. These systems were predominately hose drip systems in vineyards, microspray systems in orchards, and drip tape systems in strawberries. Table 2 shows the breakdown of systems by crop group and system type.

Table 2. Evaluated Irrigation Systems included in Database by Crop Type and Micro-irrigation method.

Crop	Drip Hose	Microspray Jets	Microspray Spinners	Drip Tape	Total
Orchards (fruit and nut)	61	111	22		194
Vineyards	50				50
Strawberry				38	38
Other Annual				3	3
Unknown	27				27
Total	138	111	22	41	312

In these evaluations, pressures were recorded downstream from the pump and at several locations in the irrigation laterals (at the emitters). Measurements were often also taken at the filter downstream of the filter station (inlet of the distribution system). In addition, all evaluations recorded the type of emitters and most recorded the type of filters and the presence and location of regulating values. Evaluators recorded if the fields were "undulating", however, we found that information inadequate, so we located as many of the fields as possible (258) on topographic maps and determined the general slope in the area, and when, possible (240 fields), estimated the elevation of the water supply and high and low elevations for the field. Based on field slope and elevation difference information, fields were categorized into 4 topographic categories: Flat (less than 4.5 ft (equivalent to 2 psi) elevation difference, low slope (less than 11.5 ft (5 psi) elevation difference), moderate slope (< 35 ft (15 psi) elevation difference), and high slope (>35 ft elevation difference). Table 3 shows the number of fields by slope category and irrigation method.

Table 3. Evaluated Irrigation Systems included in Database by Elevation Category and Irrigation Method (values in ( ) are the portion of the systems with pressure compensating emitters).

Irrigation Method	Flat	Low Slope	Moderate Slope	High Slope
Drip Hose (PC)	36 (9)	23 (5)	36 (19)	17 (5)
Micro-Jets	42	30	11	3
Micro-Spinners (PC)	8 (4)	7 (5)	4 (2)	0 (0)
Drip Tape	6	19	6	10
Total	92	79	57	30

[2] Funding provided by U.S. Bureau of Reclamation and CA Dept of Water Resources

RESULTS

Figure 1 shows the range and distribution of pump pressures (downstream of the pump and, in most cases, upstream of the filter and any valves) in the 312 micro-irrigation systems. The figure shows a cumulative distribution curve, or the percentage of the total systems with pressures smaller than the x-axis value. For example, in Fig. 1, 60% of the systems had pump pressures less than 40 psi and 40% had pressures greater than 40 psi. The range of pump pressures is wide – from about 10 to 100 psi. About 30% of the systems operated with less than 30 psi pressure, and 20% had over 50 psi pump pressure.

Also shown on Figure 1 is a cumulative distribution curve of pressure available to filter, regulate and convey the water to the emitters. This *available pressure* was calculated as:

Pump Pressure – (highest field elevation – well elevation) – pressure required by emitter.

As the figure shows, although 60% the systems use more than 15 psi (Table 1) to clean, regulate, and distribute the water, 25% of the systems use over 30 psi and 10% use over 40 psi for these purposes. These data indicate potential opportunities to reduce system pressures.

These *available pressure* data are likely biased (underestimates) because systems often were not pumping to the highest field elevation when the pump discharge pressures were measured. When pressure required to distribute and elevate the water to the emitters is reduced, the pump discharge pressure will decrease and flow rates increase unless the pump discharge is throttled with control valves or pressure regulators. This will result in a bias towards underestimation of available pressure. Consequently, many of the very low available pressures may be underestimates.

High system pressures should result in improved irrigation water distribution uniformity (DU) both by reducing the relative pressure differences due to elevation or friction loss, and by enabling use of in-field pressure regulation. Figure 2 shows the relationship between low quarter DU as calculated in the irrigation evaluation (Burt et al. 2000) and available pressure for the systems that operated on flat or low-slope fields. The figure shows no relationship between available pressure and DU, even for systems with very low pressure. This indicates there is no water distribution or water saving benefits to high system pressures.

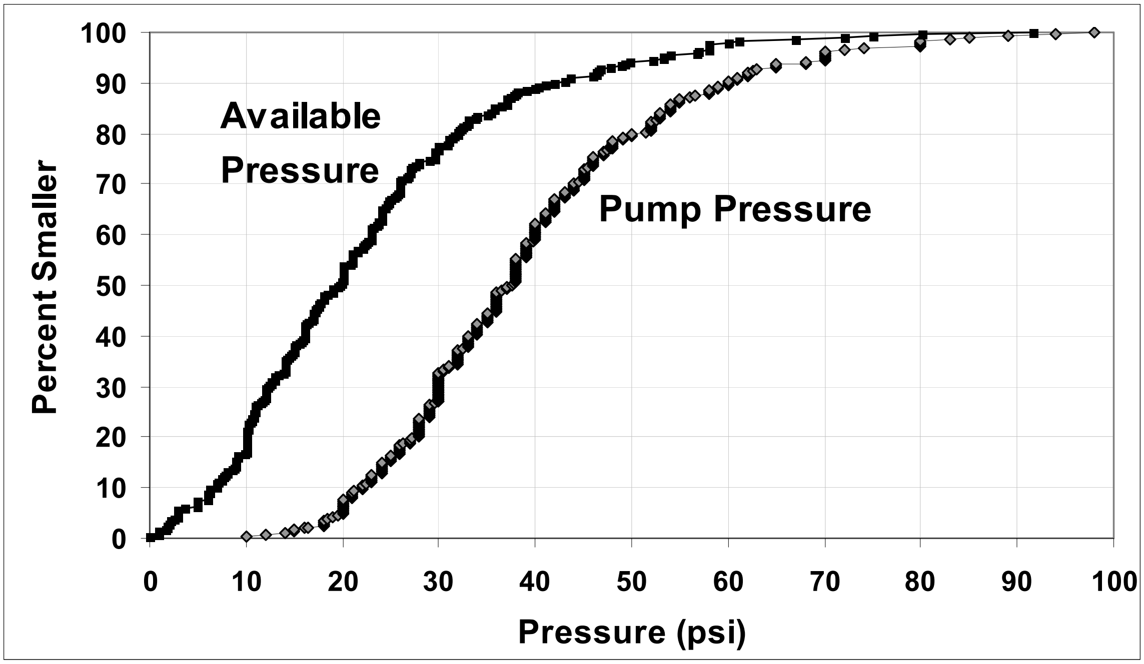

Figure 1. Cumulative distribution of pump pressures and pressure available to clean, regulate and distribute water in 312 California micro-irrigation systems.

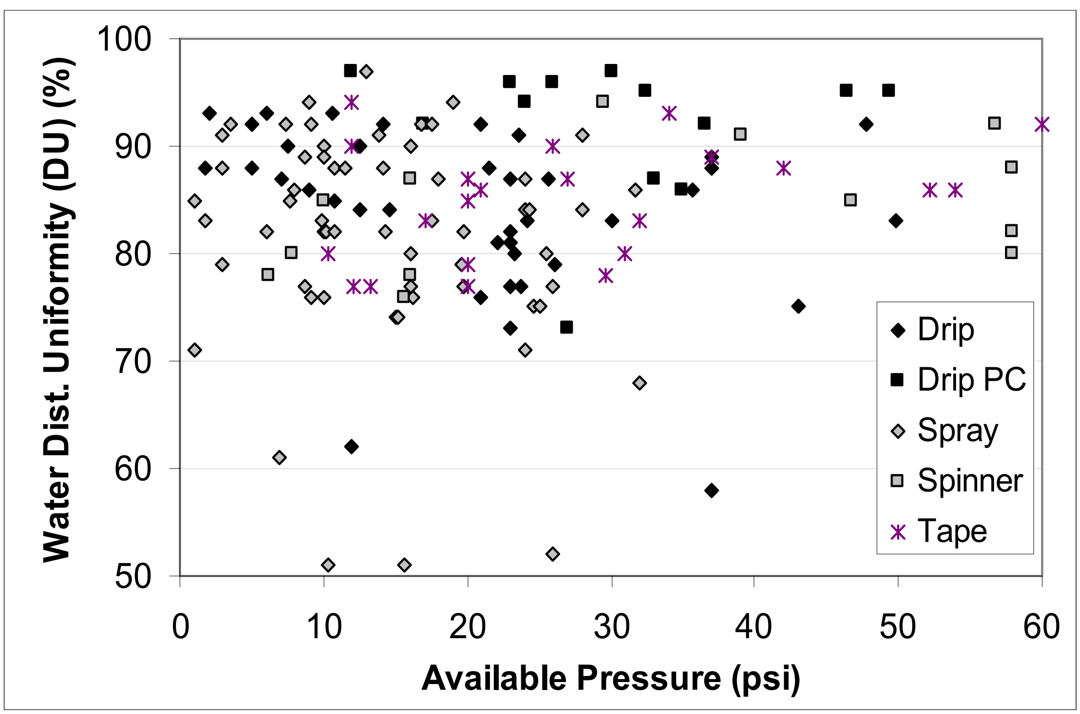

Figure 2. Measured water distribution uniformity as a function of available pressure for 150 California micro-irrigation systems on flat or low-slope fields.

Sources of Pressure Losses

Filter Station. The majority of the evaluated systems had sand media filters and/or tubular screen filters. Table 4 shows the types of filters and water source for the evaluated systems. Also listed are pressure loss expected when the filter is clean and the operating pressure required to backflush (clean) the filter, based on typical manufacturer recommendations. System designers often design for about 5 psi pressure loss for the filter, to allow for pressure loss when the filter has accumulated particulates and is ready for cleaning.

Overflow screens, commonly used with surface or low pressure water supplies, discharge water at atmospheric pressure and require a downstream booster pump for system pressure. Consequently, there is no pressure loss data for these screens.

Table 4. Numbers of different types of filters used in the evaluated micro-irrigation systems, by water source, and typical manufacturer's specified head loss when clean, and pressure required to backflush the filters

Filter Type	Water Source				Operating Pressure	
	Well	Surface	Both	Total	When Clean	Backflush
Sand Media (+ screen)	79 (6)	73 (5)	49(3)	201 (14)	1 – 3	20 – 45
Tubular Screen (vacuum)	34 (7)	14	4	52 (7)	1 – 5	0 - 25
Disk	11	7	1	19	1 – 5	35 – 45
Sand Separator	6	0	1	7	4 – 11	4 – 11
Overflow	1	8	19	28		(35)
None				2	0	0

Figure 3 shows the distribution of filter and filter station losses. Filter loss is often measured by differential pressure gauge connected to the inlet and outlet of the filters. Filter station loss is the difference between the pressure downstream of the pump and somewhere near the outlet from the filter station and inlet to the distribution system. About 1/3 of the systems indicated no measurable pressure loss across the filter. Very small loss is possible, but this likely often indicates a faulty gauge. Filter losses over 2 – 3 psi indicate the filters were not clean at the time of measurement (evaluators do not backflush filters), or that the filters are undersized or require substantial pressure loss to operate (sand separators and other centrifugal filters). Pressure loss above 7 psi indicates either a plugged filter in need of cleaning or repair, or a drastically undersized filter. There were no obvious differences in measured pressure losses for the various types of filters.

The scattered data points on Figure 3 are the filter station loss for the filter on the cumulative distribution curve (ie: same ordinate (y) value). Data points to the right of the curve indicates filter station losses in addition to those through the filter, due to fitting losses, control valves, chemigation injectors, etc. Thirty-one of the 280 systems had at least 5 psi pressure loss in addition to filter loss (or at least 8 psi loss if filter loss was listed as 0), and 15 of the systems had at least 10 psi loss in addition to the filter loss. For 7 of those systems, most of the loss was attributed to partially-closed manual or automatic pressure control valves, with valves dissipating over 15 psi for 5 of the systems. This is most likely due to a pumping plant over-designed for the conditions at the time of the measurement – for example for use of sprinklers, capacity needs for frost control, or pressure requirements to deliver water to higher fields. The right cumulative distribution curve in Figure 3 represents the filter station (including filter) loss. Twenty percent of the systems had filter station losses exceeding 8 psi.

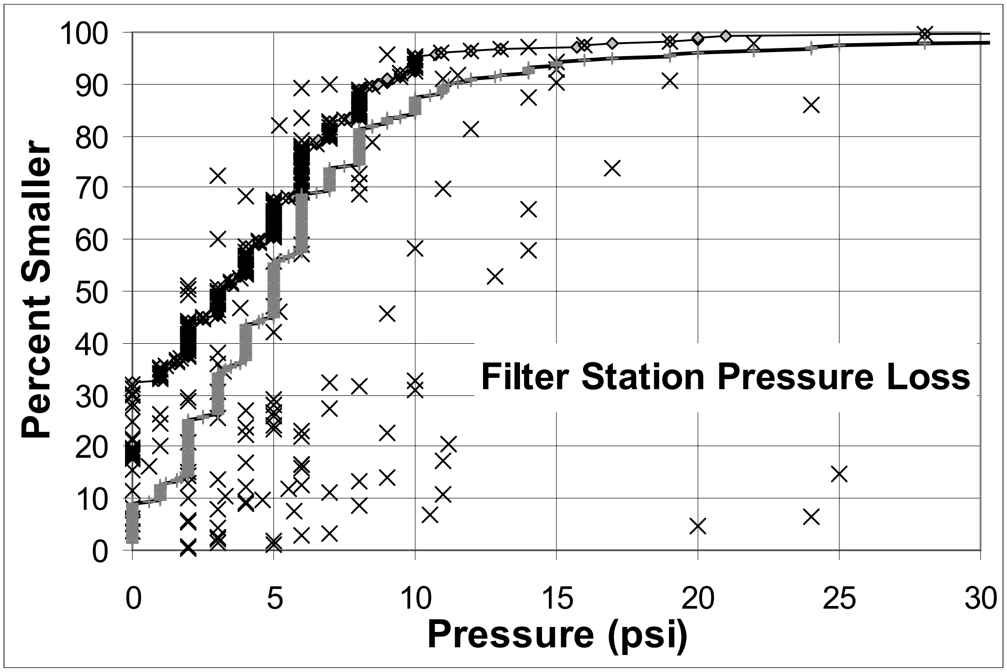

Figure 3. Cumulative distribution of pressure loss across the filters (left curve) and at the filter station (right curve). Scattered data are the filter station losses distributed horizontally from the associated filter loss.

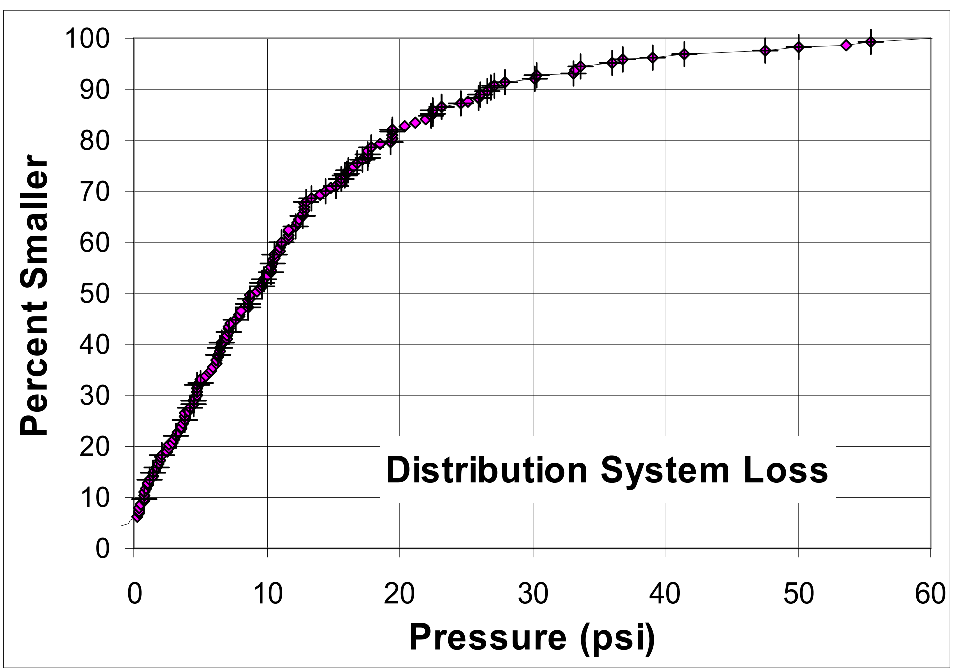

Figure 4. Cumulative Distribution of Pressure Losses in the Distribution System between the filter station and the manifolds for 163 flat and low slope systems. Cross (+) data points represent systems with pressure control valves.

Distribution System. Figure 4 shows the cumulative distribution of pressure losses in the distribution systems between the filter station and the manifold. The data represents the pressure difference between downstream of the filter station and average pressure at the inlet to the first lateral on each of three measured blocks. Thus, this represents distribution losses not to the furthest point but to an average of a near, far, and intermediate block, and does not include losses in the manifold. Elevation changes from the well to the highest field have been subtracted from the losses so that they represent only friction losses, and only flat or low slope fields have been included.

Nearly 50% of the systems exceed 10 psi pressure loss in the distribution system (main and sub-main pipeline and control valves), and nearly 20% exceed 20 psi loss. These high losses are surprising considering surveyed designers estimate typical main and submain losses at 3 – 6 psi. Many designers use two criteria for pipeline design – flow velocities less than 5 ft/sec between the filter station and block valves, and total distribution loss (including laterals) less than 3 psi downstream of the block valve. Limiting flow velocities to 5 ft/sec will result in flow velocity varying between 3.5 and 5 ft/sec (depending on flow rate and available pipe sizes) and pressure losses that average about 5 psi per 1320 ft (1/4 mi - the length of a square 40 ac field) of pipeline. Distributing water from one corner of a 40 ac field to the farthest block at the opposite corner would result in about 10 psi loss with the 5 ft/sec criteria. These data seem to indicate that either some systems use undersized pipelines, or there are significant losses in addition to pipeline friction losses. The most likely source are losses in control valves and block valve and fittings.

Ninety-five of the 312 systems had pressure control valves at the block (set) control points, 31 systems used pressure regulation at the inlet to the laterals, and 6 systems used both block and lateral pressure control valves. Seventy-six of 171 systems (45%) on flat or low slope fields used pressure control valves in the distribution system (cross data in Fig. 4). Over 75% of the systems on flat or low slope fields with distribution system loss over 15 psi had pressure control valves. Thus, a significant portion of the high distribution system losses shown in Fig 4 likely occur at pressure control valves.

Manifolds and Laterals. Figure 5 shows the average measured pressure loss in the manifolds of the 154 systems that operated on flat or low-slope fields without hose pressure control. These data were calculated as the difference between the inlet pressure in the lateral nearest the manifold inlet and the last lateral on the manifold, and represent the average of three measured manifolds on each field. Ten percent of the systems had slightly higher pressure at the tail end of the manifold than at the head end, and an additional 15% had no average pressure loss in the laterals, indicating the manifolds sloped downhill and elevation gain equaled or exceeded friction loss. However, 20% of the systems exceeded 2 psi pressure loss in the laterals and 10% exceeded 3 psi loss, which is excessive both for good distribution uniformity and pressure loss.

Another source of pressure loss in the manifold is the lateral inlet assembly. Hose screens are often used at the inlet to drip and microspray hose laterals. The evaluators checked these screens for plugging, and rechecked lateral pressures after cleaning. Before and after pressure measurements indicate the pressure loss due to hose screen plugging. On 18% of the drip hose and microspray systems, these screens generated over 1 psi of pressure loss, and on 10% of the systems, the loss was greater than 2 psi. For drip tape systems, small diameter polyethylene "spaghetti" tubing is usually used to connect the drip tape to the manifold. These connectors are often undersized in strawberry drip systems and generate substantial pressure loss. These losses were measured or calculated in the 38 strawberry drip systems, and over 50% caused more than

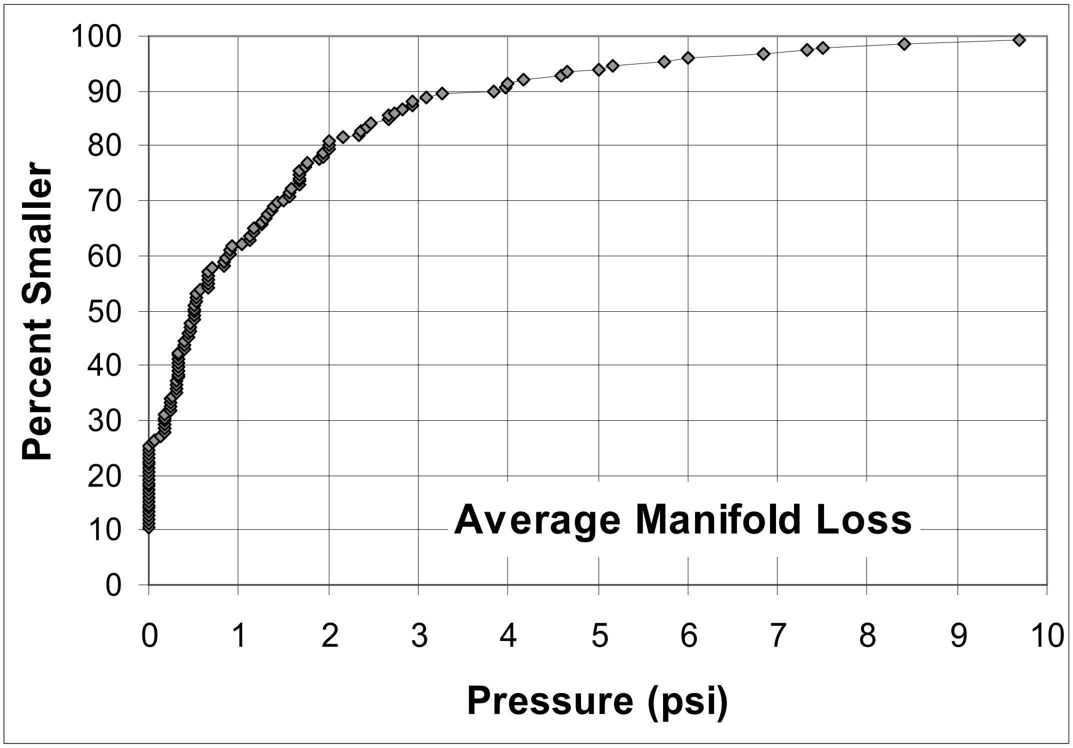

Figure 5. Cumulative Distribution of average measured pressure loss in the manifold for flat and low slope fields without hose pressure control.

2 psi of pressure loss. In 30% of the systems, these connectors caused over 4 psi of pressure loss.

Figure 6 shows the average pressure loss in the lateral hoses and tapes for 5 types of micro-irrigation systems. As expected, drip tapes, which have the lowest operating pressure, have the lowest losses, and micro-spray spinners which operate at relatively high pressures, and drip hose with pressure compensating (PC) emitters, have the highest loss. High distribution uniformity requires less than 10 or 15% pressure variation within laterals for non-PC emitters, with would be about 1 psi loss in tape, 2 psi loss in hose drip, and 3 psi in microsprays. About 50% of the systems exceed these limits. All but one of the spinners with pressure loss over 3 psi had pressure compensation. Where PC emitters are used to compensate for undulating terrain, they solve an important problem. Where they are used to allow use of long laterals or small hose size, they reduce initial costs at the expense of higher energy costs. About one-third of the PC drip systems were used on flat or low-slope fields, but over 80% of the PC spinners were used on flat or low-slope fields.

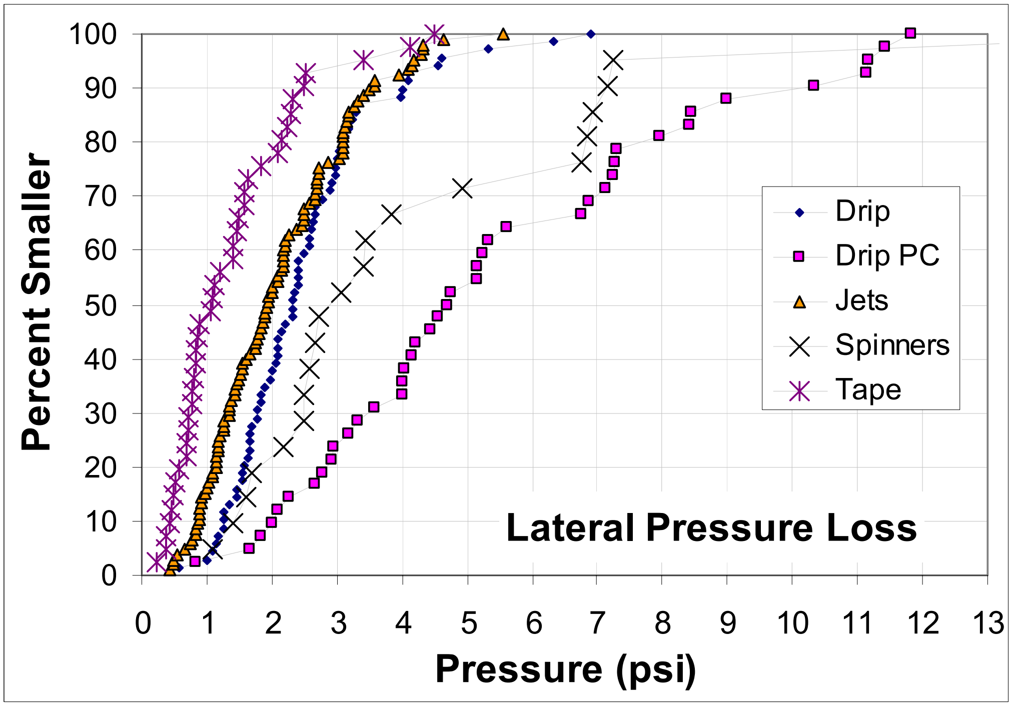

Figure 6. Cumulative distribution of average pressure loss in the laterals for 5 types of micro-irrigation systems.

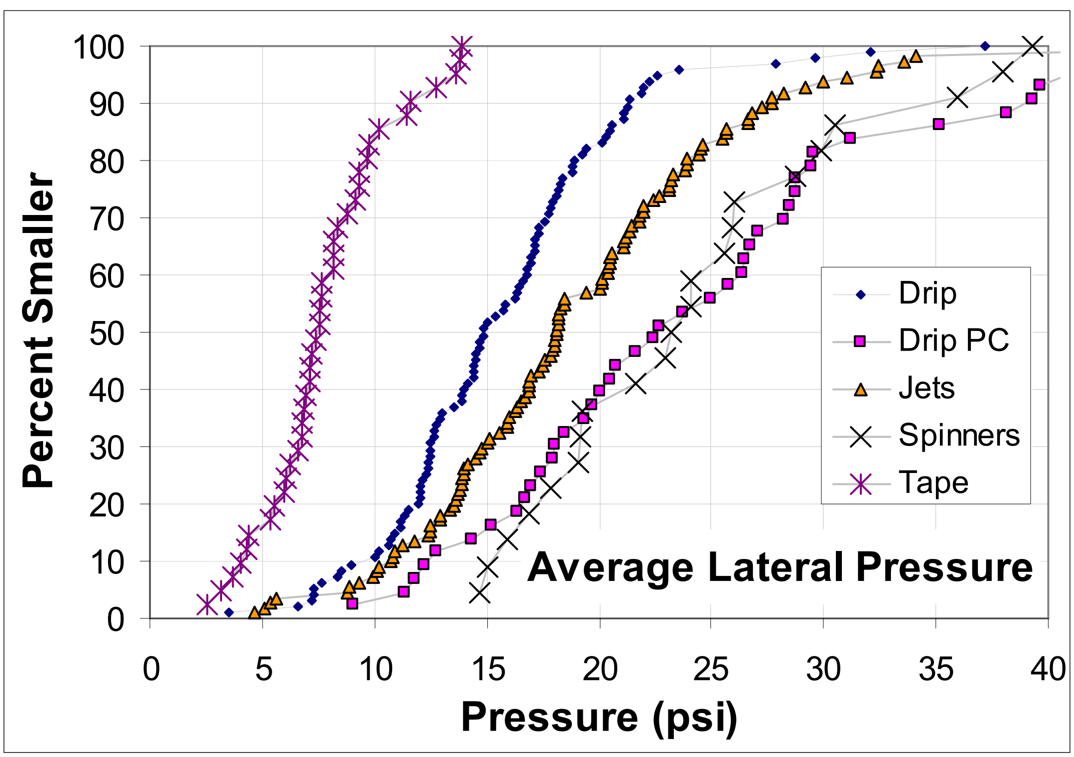

Figure 7. Cumulative distribution of average measured lateral pressure for 5 types of micro-irrigation systems.

The average pressure in the laterals is shown in Figure 7 for the 5 types of emitters. Non-PC drip emitters and jets have no minimum or maximum pressure allowance other than the pressure capacity of the hose or tape. Micro-irrigation designers consistently specify 8 – 10 psi for thin-walled drip tape, based on tape burst pressure; 12 – 15 psi for thick walled tape and hose, based on maintaining adequate velocities in the tortuous flow path to flush sediments; 20 psi in jets to create adequate wetting diameters; and 25 psi in spinners to assure rotation. These values are near the median measured for the various systems. Although tape systems are constrained by burst pressures, about 20% of the remaining systems exceeded these target values by 5 psi. In undulating terrain, high lateral pressure is required to maintain minimum pressures. Otherwise, this extra pressure increases energy used without substantial improvement in water distribution uniformity. Over 50% of the drip (non-PC) and jet systems with high lateral pressures were on flat or low-slope fields.

POTENTIAL FOR REDUCING SYSTEM PRESSURES

The evaluation data indicate that, although a portion of the systems operate at low to moderate pressure, there is potential to reduce pressure in many systems. Table 1 suggests that 15 psi should be adequate to clean and deliver water to the emitters for most systems (not including lift to high fields). Micro-irrigation designers in the San Joaquin valley estimated the pressure required to clean and deliver water to emitters between 11 and 25 psi for flat fields. Figure 1 shows that about 60 percent of the measured systems exceed this value, and 30% of the systems exceed by over 10 psi. Even if we allow for an additional 5 psi for pressure regulation on the one-third of the fields with undulating terrain, there is potential to reduce system pressures by and average of 15 psi in those 60% of the systems with excess pressure. Much of the potential savings are on the 20% of the fields with the highest available pressures, where the average potential savings is 29 psi.

Table 5 shows the annual energy cost savings (@ $0.12 per kw-hr) for a range of system pressure reductions for varying field sizes (3.64 kw-hr is required to pressurize 1 ac-ft of water to 1 psi @65% pumping plant efficiency). A 15 psi pressure reduction for an 80 ac. orchard or vineyard micro-irrigation system (with appropriate pumping plant modifications) would save $2000 per year in energy costs.

Table 5. Potential annual energy cost savings from system pressure reduction.

Area	Irrigation	System Pressure Reduction (psi)					
	Amount	2	5	10	15	20	30
acre	ft/ac						
1	3	$2.62	$7	$13	$20	$26	$39
1	4	$3.49	$9	$17	$26	$35	$52
40	3	$105	$262	$524	$786	$1,048	$1,572
40	4	$140	$349	$699	$1,048	$1,397	$2,096
80	3	$210	$524	$1,048	$1,572	$2,096	$3,144
80	4	$279	$699	$1,397	$2,096	$2,795	$4,192
160	3	$419	$1,048	$2,096	$3,144	$4,192	$6,288
160	4	$559	$1,397	$2,795	$4,192	$5,590	$8,385

Assumptions: 65% pumping plant efficiency; $0.12/kw-hr electricity cost.

If these data are representative and pressures could be reduced by 15 psi on 60% of the 1.7 million acres with micro-irrigation in CA, this would save 220 gigawatt-hr/yr of power and about

90 megawatts of peak demand. The potential for reducing energy use is substantial.

The data consistently show that for most sources of pressure loss, the range of losses is large – about a quarter of the systems have very low loss and about 20% have high loss. Figure 2 shows that irrigation uniformity is not low in low-pressure systems. This shows that low pressure systems can work in many situations, and most of the potential for reducing energy loss is concentrated in a small portion of the systems. It is more difficult from the irrigation evaluation data to determine the reasons for the high losses, since the data was not collected for the purpose of assessing energy efficiency.

Much of the potential for pressure loss reduction is in the distribution system. Even though designers state that they design for only 3 – 6 psi losses in the distribution system, nearly 50% of the systems on flat and low-slope fields had more than 10 psi loss between the filter station and manifolds, and 20% of the systems had more than 20 psi loss. These losses include friction loss in pipelines, fittings, and valves; and pressure drop at regulators. Most designers use a limiting pipeline design criteria of 5 ft/sec velocity, which will usually result in friction loss in the range of 0.2 – 0.5 psi/100 ft and over 7 psi loss to the most distant manifold in typical systems. Designers generally do not calculate fitting losses, but allow for fitting loss as part of a "safety factor".

The economics of initial cost vs. energy cost for distribution system pipe sizes and layout is not difficult to calculate. For example, increasing pipe size by one size (ie: from 6" to 8") will increase material costs for the pipe by about 40% and reduce pressure loss by 60 to 80%. If a designer uses 5 ft/sec flow velocity as the size criteria for a 1320 ft. 6" mainline, increasing the pipe to 8" will save about 2.5 psi, with an annual energy savings of about $175 (for 160 ac-ft pumped, 65% pumping plant efficiency, and $0.12/kw-h electricity cost) and an increased initial cost of about $900. Whether the larger pipe is economic for the farmer depends on his availability and cost of capital and the inflation in energy cost. Full assessment would also require evaluating the impact of the larger pipe on more uniform pressure and water distribution. Greater than 10 psi pressure loss in the distribution system will result in substantially reduced DU unless pressure regulation is used.

Forty percent of the systems on relatively flat fields used block or lateral hose pressure regulators. Designers typically allow 5 psi for operation of pressure regulators, and many of the high distribution loss systems on flat and low-slope fields had regulators. Pressure regulation on flat fields is not necessary, but is a means of simplifying system design and operation, reducing the cost of distribution system pipelines, and reducing risk from operational errors. Regulation allows the operator to vary set sizes and use pumps that produce excess pressure for the micro-irrigation system. Although regulators are necessary to make micro-irrigation practical on undulating fields, they are overused on flat fields where good hydraulic design can replace the need for regulation. However, the added energy cost of less than $9 per acre per year (4 ac-ft of water @ 5 psi) for a fruit or vegetable crop, may be a good investment if it improves system flexibility and water distribution uniformity, and reduces risk of system (and crop) damage from over-pressured laterals or fittings.

Pressure loss is substantial in some systems at the lateral inlet. High losses were measured or estimated in undersized spaghetti tubing for drip tape systems in strawberries, and plugged hose screens. Undersized shutoff ball valves at lateral risers can also cause substantial pressure loss. These pressure losses can result in poor water distribution uniformity, because they often aren't uniform. However, they will not likely result in reduced energy use because theses losses are not normally calculated by designers and thus are not added into pump pressure requirements.

In low pressure systems, pressure required to backflush the filter may establish the low limit on system pressure. Backflush pressure requirement varies with the type of screen and manufacturer (Table 4). Manufacturers may over-specify backflush requirements to allow for excessive pressure loss in the backflush discharge piping and for infrequent backflushing. The majority of the evaluated systems used sand media filters. With proper piping and operation, sand media filters can adequately backflush at less than 20 psi. Self-cleaning screen and disk filters require 10 to 20 psi more pressure than media filters for effective backflushing, but generate less backflush water. Designers should help micro-irrigation system purchasers evaluate the real cost of a filter system that increases system pressure requirements. For example, a filter system that increases system pressure requirements by 5 psi on a 160 ac. orchard will increase annual energy cost by about $1400.

Designers allow for a safety factor when designing micro-irrigation systems of from 2 to 5 psi. The reasons are to cover uncalculated fitting losses, higher than anticipated filter losses, pumps that do not operate as specified, and well drawdown. Although it is easy to reduce pressures in an over-pressurized system (ie: partially close a valve), it is difficult to increase pressures in an under-pressurized system, and farmers will likely fault the designer if a system has inadequate pressure or capacity at the field. As with the 5 psi filter backflush example above, this contingency can be expensive in terms of energy costs for large systems. In some cases, this extra pressure helps provide filter backflush pressure.

A common constraint to energy efficient design for micro-irrigation systems is the desire to use a pre-existing pump or to use a pump that is also used for high pressure sprinkler systems. System designers often point out the farmer criteria to match a system to an existing well pump. Some of the very low pressure systems in the dataset were likely designed to match the discharge characteristics of existing wells used for flood irrigation. Many of the high pressure systems utilize pumps that also pressure sprinklers during crop establishment, frost control, and/or to irrigate rotation vegetable crops. Although excess pump capacity can sometimes be used to increase flow rates without increasing system pressure, high pump efficiency cannot be maintained at two operating points. I suspect that a substantial portion of the high pressure systems are the result of a pre-existing or specified high pressure pumping plant. Before using an existing over-capacity pump, the designer should evaluate the energy benefits of modifying the pump or installing a new pump designed for the system. For systems that occasionally require additional pressure or capacity, such as to sprinkle newly-planted or frost-endangered crops, use of a booster pump should be evaluated. A 20 HP booster pump that is used 10% of the time to boost 700 gpm from 30 to 60 psi will save 35,000 kw-hr ($4000) per year.

Systems that irrigate undulating ground require a pumping plant to irrigate the area at the highest elevation, and thus, the pump is over-designed for the rest of the area. Like the example above, booster pumps that are used to produce the occasional high pressure needs will save significant energy and should be evaluated.

Variable frequency drives (VFD) can be very efficient in systems that operate over a range of pressure or flow rate requirements. On systems with varying flow rate requirements, VFDs can maintain a constant pressure. In systems on undulating ground that irrigate equal-sized (and flow rate) sets at varying elevations, they can maintain a constant flow rate and vary speed to automatically maintain the pressure required at the manifold. In both cases, not only does the VFD reduce energy when full capacity is not required, but it also can avoid the use of pressure regulation and the pressure loss required by regulators. A VFD can also efficiently provide the higher flow or pressure required when the filter backflushes. Variable frequency pumping plants must be well designed to insure that the pump operates most of the time in its high efficiency range. Variable frequency drives also have energy losses (3 - 5%) that must be considered when evaluating their benefits. Costs of VFDs have decreased as technology improves and demand expands. A 50 HP VFD controller can currently be installed for about $10,000 (compared to $3000 for a standard pump panel. In an 80 ac. system in which pressure requirements vary by 30 psi, this cost could be repaid in 4 years.

There are many choices made during system design that impact pressure requirements. Most choices that reduce energy use increase initial system cost. Designers should evaluation the economic tradeoffs and discuss them with the grower. Unfortunately, designers, who commonly work for equipment dealers, may propose low cost systems without revealing the high energy costs in order to win a contract bid. Growers, even when given the economic information, sometimes choose to save initial costs in spite of higher deferred energy costs.

Conclusions

There is potential to reduce energy use in California micro-irrigation systems. Most of the potential savings is in the 20% of the systems that operate at highest pressures. Distribution system pipelines and pressure regulation are the largest sources of pressure loss. Some high pressure systems use a single pumping plant to operate both micro-irrigation and sprinkler irrigation. Booster pumps or variable frequency drives could potentially save significant energy costs for these dual systems or systems that irrigate undulating land.

Recommendations

- Economically evaluate the best pipe sizes for distribution systems.
- Use pressure regulators or PC emitters only where the benefits in initial costs, water distribution uniformity and system operation is greater than the energy costs.
- Design filter backflush systems that do not limit system pressures.
- Use lateral inlet fittings (ball valves, hose screens, spaghetti tubing) that cause little (<0.5 psi) pressure loss.
- Use booster pumps or variable frequency drives when a pumping plant must operate over a range of pressures or flow rates.

REFERENCES

Irrigation Journal. 2001. 2000 Annual Irrigation Survey Continues Steady Growth. Irrigation Journal, Jan/Feb 2001 pp 12-30, 40,41.

Burt, Charles, R. Walker, S. Styles, and J. Parrish. 2000. Irrigation Evaluation. Irrigation Training and Research Center (ITRC), Cal Poly, San Luis Obispo. 200pp.

Acknowledgments: The authors wish to thank the Irrigation Training and Research Center and Kings River Conservation District for sharing the Irrigation Evaluation data that was used in this analysis.

Trade names mentioned are for the benefit of the reader and do not imply endorsement or preferential treatment by USDA.