Low Pressure Drip/Micro System Design – Analysis of Potential Rebate

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Drip/micro irrigation systems are often referred to as "low pressure" systems because the required emitter pressures are relatively low (6-12 psi). However, the pump discharge pressures of systems on flat ground throughout California average 40 psi. This report examines readily attainable system losses by examining individual components of the drip/micro system.

Bottom Line **– Pump discharge pressures can be reduced by 13 to 17 psi if the appropriate system hardware is selected and pipelines are sized to minimize friction losses.**

In the southern San Joaquin Valley, the per-acre energy savings and demand reduction as a result of this reduction in pump discharge pressure is shown in the summary table below. Based on the kWh/Acre/Yr savings, a cost savings of $25-$30 per acre could be expected per year.

Summary Table: Estimated annual kilowatt-hour (kWh) per acre and kilowatt (kW) demand per acre in the southern SJV for a typical year

Crop Category	Energy Savings (kWh/Acre/Yr)	Demand Reduction (kW/Acre)
Deciduous Orchards	**192**	**0.10**
Vines	**125**	**0.08**
Row Crops (Tape)	**132**	**0.13**

As is often the case, system improvements bring with them an increased cost for appropriate hardware (valves, filters, emitters, larger pipelines, etc.). A rebate program would be beneficial to encourage energy efficiency by lowering system pressure demands. A good rebate program would not only specify discharge pressures based on readily attainable system pressure losses and elevation changes throughout the field, but would also specify a reasonable new system distribution uniformity of 0.92. A high new system distribution uniformity ensures that the new system will apply water uniformly over the field, potentially minimizing irrigation water losses below the root zone and providing excellent distribution of fertilizers through the irrigation system.

Low Pressure Drip/Micro System Design

Background and Baseline Data

The terms "drip irrigation", "microirrigation", and "trickle irrigation" are often used interchangeably, although they can technically refer to the design of the final emission device. These systems are often referred to as "low pressure systems". A typical California pump discharge pressure is about 35-45 psi (pounds per square-inch, pressure measurement) on flat ground (even though the emitter may need only 6-12 psi pressure). For a detailed explanation of options and designs for drip/micro systems, refer to Burt and Styles (2011).

ITRC maintains a database of over 700 drip/micro system distribution uniformity evaluations that have been conducted throughout California every summer since 1997. Approximately 350 of these evaluations were selected throughout California's Central Valley where the systems are constructed on relatively flat terrain. From these evaluations, the average pump discharge pressure and standard deviation of the discharge pressures is shown in the following table.

Table 1: Average and standard deviation of pump discharge pressures for 350 drip/micro systems on flat terrain in the California Central Valley

Sample Size	Average Pump Discharge Pressure	Standard Deviation
350	40 PSI	13 PSI

A study by Trout and Gartung (2002) highlighted several important topics related to energy and drip/micro irrigation. An important aspect of their findings is the discrepancy between the fact that while typical emitters only need 6-12 psi of pressure, drip/micro system pump discharge pressures average about 40 psi on flat ground. With advances in valve and filtration design in recent years, proper design of drip/micro systems should be able to reduce the overall discharge pressure significantly.

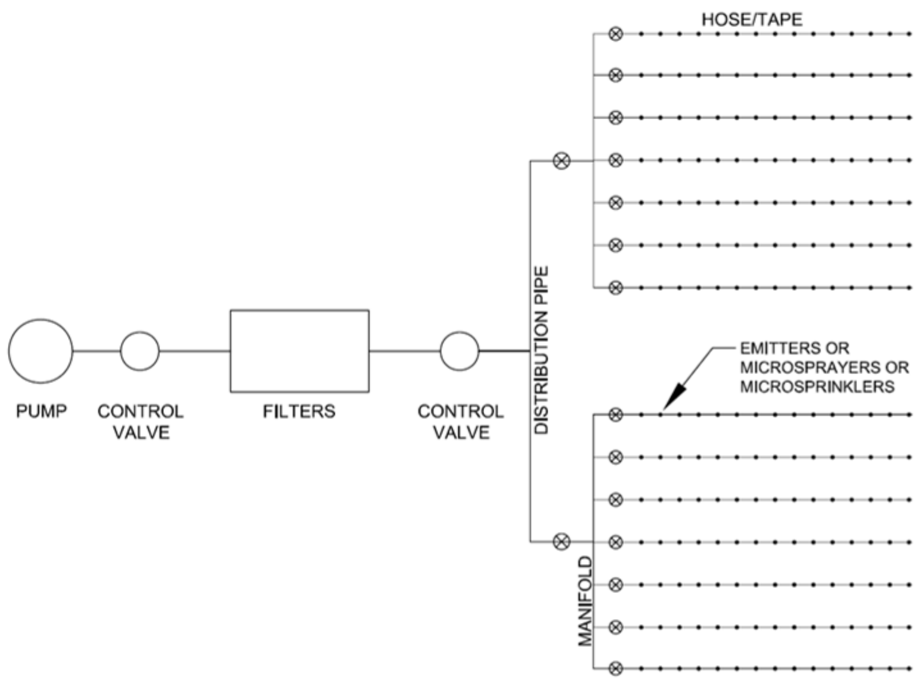
Designing a system for a lower pump discharge pressure will reduce both electrical load (demand) and annual energy consumption of the motor driving the pump over the life of the system.

This document will outline reasonable drip/micro system component losses and develop criteria for appropriate system designs based on the traditional distribution uniformity plus a maximum pump discharge pressure target.

Readily Attainable Pressure Losses

Figure 1 is a conceptual sketch of a drip/micro irrigation system with key components.

Figure 1: Drip/micro irrigation system schematic



To minimize pressure requirements at the pump discharge, one must consider the pressure requirements for water to flow through each of these components.

1. <u>Control valves near the filter</u>. All control valves have friction loss, but there are significant differences between various sizes and models. There is very little new knowledge here, and some excellent control valves exist for this location.

2. <u>Filters</u>. This is one component that has significant room for improvement. Therefore, ITRC conducted a major study of media filter performance as part of this contract. The large pressure loss that is built into drip and micro irrigation systems for filters is not needed if the correct filters are used. The major factors are:
    a. Some filters, such as the various internal-wand-cleaning screen filters, and various disc filters, require 35 psi minimum to properly backflush.
    b. Media filters (the most common type) are generally thought to require 35 psi to backflush. The ITRC filter study shows this is not a universal requirement.

   Because the filter backflush pressure requirement is so large, there is typically no reason for designers to select low pressure loss valves and fittings within the irrigation system. In other words, the items discussed below are not very important unless the proper filter is selected.

3. Control/pressure regulation valves within the distribution system, and at the heads of tapes and hoses. Depending upon the model and design, there can be significant pressure savings if valves are carefully selected. There are two types of pressure regulation valves:
    a. Pilot-operated valves. These are usually 2" or larger in diameter, and are used at the heads of manifolds, especially with tape systems. There is a major, little-known hydraulic fact about many of these valves: if the downstream pressure is 8 psi (typical for drip tape), there may be a 10 psi loss across the valve for a flow of 100 GPM. But if the downstream pressure is 20 psi, there may only be a 2 psi loss across the valve for a flow of 100 GPM. Manufacturers publish the 2 psi value, but not the 8 psi valve. Irrigation designers do not know which valves have these characteristics, or that they even have them. Designers do know that they need a substantial "safety factor" of extra psi for the pump to take care of things like this.
    b. Pre-set pressure regulators. These pressure regulators are typically used at the heads of hoses in hilly terrain. They can have large (3-6 psi) friction losses across them when wide open.

4. Fittings on hose risers can be small and have appreciable friction loss. There is no standard in the industry for these fittings, and the friction loss of the various assemblies that are used is not well known.

5. Drip hose/tape hydraulics. These are fairly well understood. All of the major manufacturers have good hydraulics programs that they provide to irrigation designers. ITRC has a similar program for education that is used by many designers. They all perform the same functions – the uniformity of water discharge, friction, pressure requirements, etc. are automatically computed if one inputs the slope, hose diameter, emitter specifications, and other required information.

6. Emitters, microsprayers, and microsprinklers. These are the final emission devices. Many of the designs have not changed for many years. For discussion, there are two basic types of emission devices: Those with fixed holes, and those with some type of pressure compensating (PC) ability that requires some type of flexible diaphragm inside the emission device. There are some very interesting possibilities at this level, which are described below:
    a. Standard, fixed hole/path emitters must have a minimum pressure of 6-12 psi just to maintain good uniformity of discharge along the hoses, and between hoses. If there is elevation variation, the optimum average pressure needs to be higher to maintain good uniformity.
    b. Pressure compensating (PC) devices present interesting possibilities:
        i. There are very few PC emitters (discharging somewhere between 0.5 and 1.0 Gallons/hour) that can operate very well at pressures as low as 4 or 5 psi. This means that at a wide range of pressures, say between 4 and 35 psi, the flow rate is almost identical. Especially for hilly terrain, this feature can offer substantial (at least 10 psi) pressure reduction benefits.
        ii. Microsprinklers are emission devices that have a stream of water (e.g., 15 Gallons/hr) that is rotated to provide a large amount of ground coverage. The most popular PC microsprinklers do not work well until the pressure at the microsprinkler is about 25 psi. ITRC was unable to locate any commercially available low pressure PC microsprinklers.

iii. Microsprayers are emission devices with relatively large flows (e.g., 15 Gallons/hr) that discharge from a nozzle, hit a fixed plate, and then spray out with multiple jet patterns. Bowsmith Industries (Exeter, CA) recently developed a PC microsprayer that begins to function well at relatively low pressures (8 psi). As with PC emitters, this is an important addition for hilly terrain.

Considering the individual component pressure requirements, the readily attainable pressure losses are shown in the following table.

Table 2: Readily attainable pressure losses

Item	Pressure (psi) required for different systems	
	Tape	Tree/vine
Emitter	6	10
Hose/tape	3	3
Fittings, valve losses	2.5	2.5
PVC main and manifold	3.5	3.5
Filter	5	5
Control valves, check	3	3
TOTAL	**23**	**27**

Energy Savings

Reducing the pump discharge pressure from an average of 40 psi to 23 psi for tape and 27 psi for trees and vines will result in lower energy consumption assuming that the same amount of water is applied to the crops in both cases and the overall pumping plant efficiencies are the same.

Table 3 shows the estimated annual applied irrigation water per acre for three crop categories under drip/micro irrigation in the southern San Joaquin Valley (SJV). These values were obtained from the ITRC website (ITRC, 2003) for the California Department of Water Resources ETo Zone 16.

Table 3: Estimated annual applied irrigation water for three crop categories in the southern SJV

Crop Category	Applied Irrigation Water (AF/Acre/Year)
Deciduous Orchards	3.7
Vines	2.4
Row Crops (Tape)	2.0

The energy savings per acre-foot of applied water can be computed as:

$$\frac{kWh}{AF} = \left(\frac{\Delta TDH}{OPPE/_{100}}\right) * \ 1.023$$

Where,

kWh/AF = savings in kilowatt-hours per acre-foot of water per year
ΔTDH = difference discharge pressure between the baseline (40 psi) and the readily attainable pressure loss shown as total dynamic head (feet) where (TDH = 2.31×psi)
OPPE = overall pumping plant efficiency as a percent

The energy savings per acre is computed as:

$$\frac{kWh}{acre} = \left(\frac{kWh}{AF}\right) * \ AF$$

Where,

kWh/Acre = savings in kilowatt-hours per acre per year
AF = acre-feet of applied irrigation water per year

Assuming an overall pumping plant efficiency of 60% (considered good to very good for typical motor sizes used in agricultural pumping), the estimated energy savings per acre per year resulting in a reduction in discharge pressure from 40 psi on average to 23 psi or 27 psi (for row crops with tape or deciduous orchards and vines, respectively) is shown in **Table 4**.

Table 4: Estimated per acre annual energy savings through reduced pump discharge pressures

	Pump Discharge Pressure Difference		Savings	
Crop Category	**Δpsi**	**ΔTDH**	**kWh/AF**	**kWh/Acre/year**
Deciduous Orchards	13	30.0	51.2	**192**
Vines	13	30.0	51.2	**125**
Row Crops (Tape)	17	39.3	67.0	**132**

Demand Reduction

By reducing the required pump discharge pressure, the electrical demand or load of the motor is also reduced. Irrigation systems are, for the most part, designed to meet the peak evapotranspiration demands of the crop that is being irrigated. In some cases the systems may be designed considering special constraints such as weekday operation only or to operate during the non-peak electrical period. However, in many cases the systems are designed so that the pump runs continuously during the peak evapotranspiration period. In California, the peak evapotranspiration period of most crops coincides with the peak electricity demand period (i.e., June-August).

Peak monthly crop evapotranspiration data for a typical year was obtained for the crop categories shown in **Table 5** (ITRC, 2003) for the southern SJV. The estimated peak irrigation demands in gallons per minute per acre (GPM/Acre) was computed and is shown in the table.

Table 5: Estimated peak irrigation demands (gross requirement) for three crop categories in the southern SJV (ETo Zone 16)

Crop Category	Peak Irrigation Demands (GPM/Acre)
Deciduous Orchards	10.3
Vines	8.2
Row Crops (Tape)	10.4

The reduction in demand can be computed based on the flow rate demands shown in **Table 5**, an assumed overall pumping plant efficiency of 60%, and the reduction in total dynamic head for the low pressure drip/micro system design.

$$kW = \frac{(GPM * \Delta TDH)}{(3960 * \frac{OPPE}{100})} * 0.746$$

Where,

kW = reduction in kilowatt demand per acre

ΔTDH = difference discharge pressure between the baseline (40 psi) and the readily attainable pressure loss shown as total dynamic head (feet) where (TDH = 2.31×psi)

OPPE = overall pumping plant efficiency as a percent

The estimated reduction in demand on a per-acre basis is shown in **Table 6**.

Table 6: Electric demand reduction through reduced pump discharge pressure requirements in the southern SJV

Crop Category	Pump Discharge Pressure Difference Δpsi	Pump Discharge Pressure Difference ΔTDH	Reduction kW/Acre
Deciduous Orchards	13	30.0	**0.10**
Vines	13	30.0	**0.08**
Row Crops (Tape)	17	39.3	**0.13**

Rebate Programs for Drip/Micro Irrigation

Drip/micro irrigation rebate programs offer substantial holistic potential benefits in terms of improved fertilizer efficiency and increased yield. These two items can produce more crop per drop of fertilizer and water consumed.

Such rebate programs might require numerous specific features such as the correct flow rate, appropriate air vents, good fertilizer injectors, certain thicknesses of tape, and so on. But perhaps more importantly, the following key performance results should be specified:

1. The new system Distribution Uniformity, as measured with the Cal Poly ITRC drip/micro irrigation evaluation procedures, must be greater than 0.92.
2. The pump discharge pressure shall be no greater than the following:
    a. For tape systems: 23 psi, plus the difference in elevation between the highest point in the field and the pump discharge.
    b. For emitter and micro-spray systems: 27 psi, plus the difference in elevation between the highest point in the field and pump discharge.

Perhaps there could be a $200/acre rebate for new systems meeting the pressure and uniformity criteria, plus an additional $40/acre rebate for every psi reduction below the "total" listed above.

References

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