

INDOOR IRRIGATION DESIGN GUIDE



World Leader in Irrigation Technology



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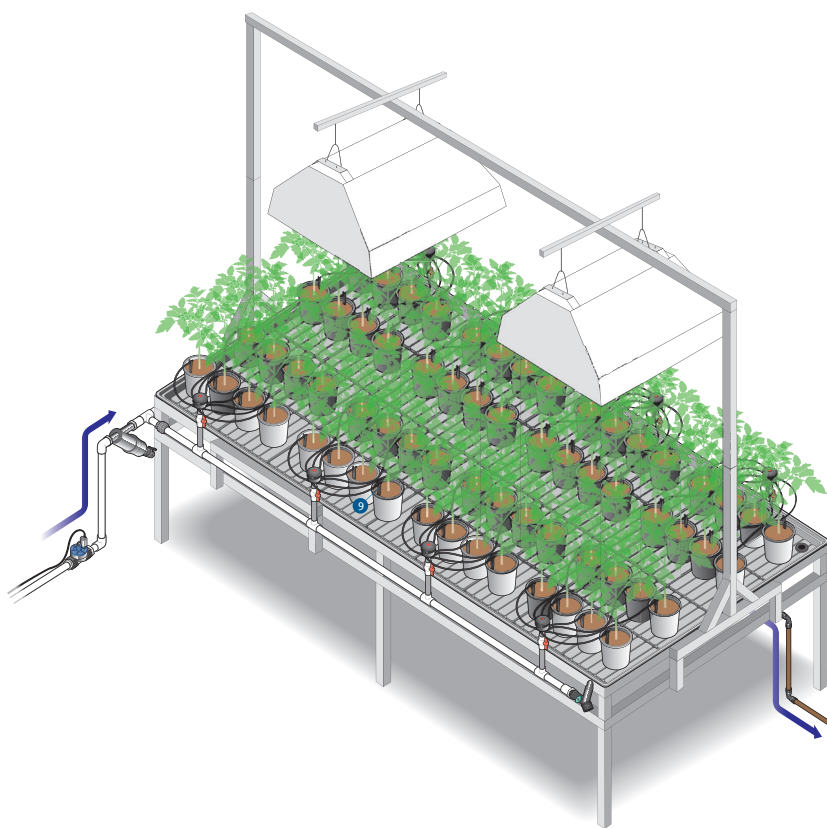
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GROWING PLANTS IN A CONTROLLED ENVIRONMENT

Why would a grower want to grow something inside?

Plant performance is strongly affected by environmental conditions. Therefore, short and mid-term changeability in weather and soil conditions are important contributors to the considerable year-to-year variability in plant growth and reproductive output in the field (Annicchiarico, 2002). This random variability often impedes a clear interpretation of observational and experimental data in disciplines such as plant biology, agronomy, forestry and ecology, and has led many plant biologists to carry out their experiments in glasshouses or growth chambers where they can at least partly control environmental conditions. Growth chambers especially offer strong control over the abiotic environment, facilitating the repetition of experiments on a year round basis. Typically, seedlings of crops, wild herbs, or trees in such experiments are grown in pots under some form of (additional) light, in an uniform substrate of potting soil or sand, with regular additions of nutrients and water. By growing plants individually and well spaced, plant-to-plant interaction is minimized, which can lead to the additional advantage of reduced plant-to-plant variability (Weiner & Thomas, 1986). Another benefit of an indoor one-plant one-pot approach is that plants can be treated and manipulated easily, including the handling of large numbers of replicates by means of automated systems, which facilitates phenotyping at a highthroughput level (Fiorani & Schurr, 2013).



Plants Grown Indoors

- Cannabis
- Bananas
- Sprouts
- Scallions
- Microgreens
- Potatoes
- Strawberries
- Spinach
- Tomatoes

Water Source

Type: Utility, Private Well or Reservoir

With any growing scenario a source of water is crucial and the water quality is imperative to a healthy system and plant. Most are fortunate to have a multiple options when it comes to choosing a water source. In rural areas water is typically pulled from water locked deep in the ground or a storage reservoir that temporarily holds water until it's needed.

Here are three common water sources and a couple design details related:

- **Utility Provider:** Cities and local utility providers typically provide water safe for drinking and with basic filtration for random debris collection, a utility provider while more expensive is going to have usable irrigation water
- **Well:** Water throughout the US is encased in a number of different aquifers and while the water sits deep in the ground at a sterile temperature it does require energy to pull from such depths. Once the water is pulled to the surface, storage is involved and the energy to once again pull from tanks to distribute to emission devices is necessary.
- **Reservoirs:** Idle water on the surface is prone to algae and contaminates, ideally surface storage is contained in tanks or holding containers that regulate UV and outside exposure.



Available System Variables

GPM: Gallons Per Minute is the standard metric used to measure water application. Drip irrigation components like multi-port manifolds, point source emitters and drip line all produce water that is measured at an hourly level.

PSI: If our mass is water (GPM) then our energy behind that mass is pressure (PSI). Irrigation systems need both pressure and flow to produce water through emissions devices and into a plants root base. While the amount of water a grower has at a systems disposal can be relative to a site, the pressure can controlled by pump size.



Water Source

Reverse Osmosis Water Disposal

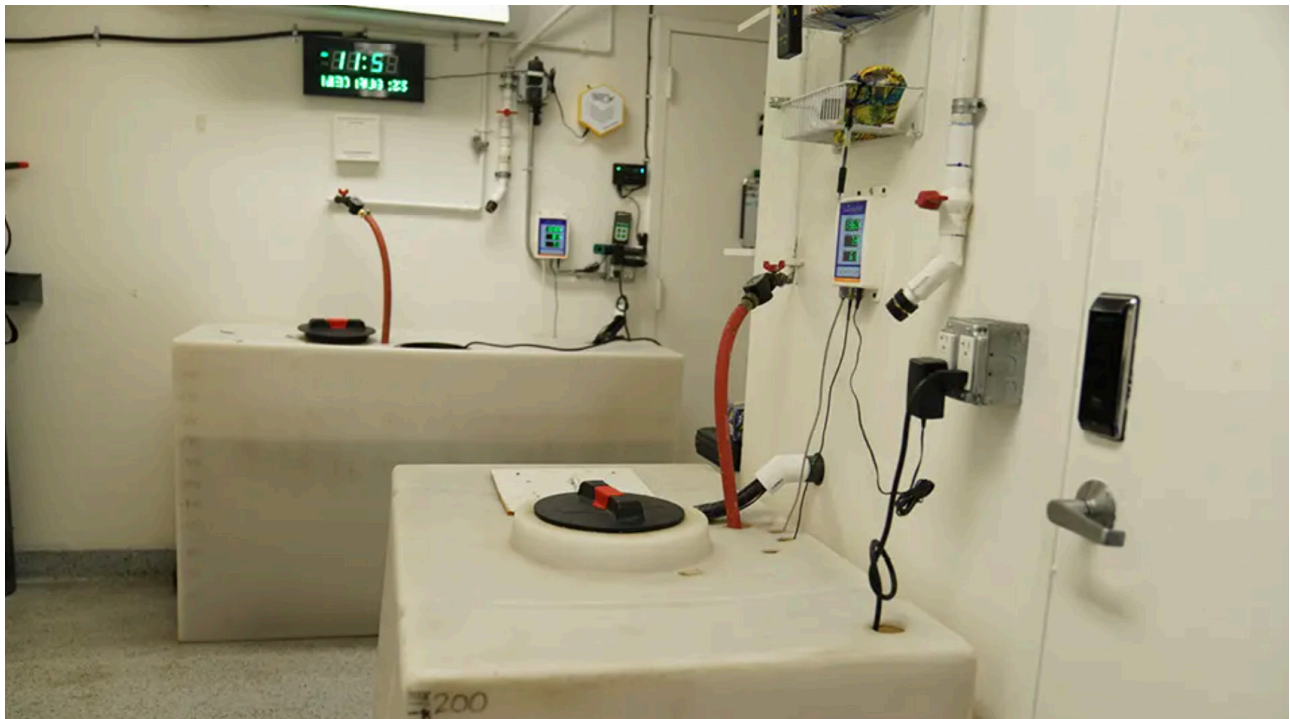
Option 1: We can achieve 60-80% recovery of concentrate by processing the water through another specifically designed RO system. The remaining concentrate water must then be disposed of or evaporated.

Option 2: Trucking - removal to waste water treatment plants.

Option 3: Evaporators - large ponds for natural or assisted evaporation. Heated tank system evaporators.

Blending

Water Blending is the ability to blend RO water, city or municipal water, treated drain water, condense water, etc. and is becoming more of a standard. Blending based on EC, flow or volume is common.



Water Sampling

Regular water sampling of source water, blended stock tank water, and outgoing irrigation water can verify fertilizer inputs. This will also help growers determine when to dispose of any recycled water that is being used.

Fertigation

Automation and Control Level Options

Applying nutrients to a root base manually is a tremendous use of time and labor. Introducing nutrients to a plants root base through an irrigation system is much more efficient.

Here are a few fertigation offerings for irrigation:

- **Venturi Suction:** The Venturi suction method uses existing system flow to pull nutrients from tanks, basins or barrells. In most cases an additional pump or energy source is not needed and little additional demand is put on the system.
- **Mazzei:** With an abundance of connection and color types Mazzei will have any injectors needs for system with a POC ranging from 1/2" - 2". Different color injectors are used for diffenret nutrients, this makes reference and maintenance a little easier.
- **Automation:** Automating any aspect of an irrigation system is going to help bring consistency to what can become a very complex network of pipes and valves. With fertigation this is no different, automatically controlling doses down to the minute is going to maximize nutrient and water usage while reducing wasteful runoff.



Using Nutrients

The types and amounts of nutrients used is going to be important when determining the demand of the irrigation system. Nutrients can be stored many ways and while storage is important it also necessary to keep storage basins close enough to the irrigations system supply that small flexible tubes can be run from tank to injector. How the system is filtered will also be determined by the type of nutrient used.

- **Granular, Compost Tea, Liquid Fertilizer:** The Venturi suction method uses existing system flow to pull nutrients from tanks, basins or barrells. In most cases an additional pump or energy source is not needed and little additional demand is put on the system.
- **Desired Injection Rates:** This depends on the type of fertilizer or nutrient being used. For bottled liquid fertilizer many growers follow the label and injection based on the recommendations. When using granular (salts) the dosing will depend on the concentration of the blends that are being made. In all cases it's recommended the grower takes a repetitive amount of water and a resrepresentative amount of fertiliier and mix them together to determine the outcome.
- **EC and pH Control:** Sensor based injection will take EC and pH sensor readings and adjust injection based on grower set parameters.

Fertigation

Nutrient Storage

- **Tanks and Drums:** Storing nutrients in tanks and drums is one of the more popular options for indoor growers. 50 gallon drums keep nutrients sealed and safe from outside contaminants while allowing for mobility without heavy machinery. Smaller containment tanks also make circulating particulates easier, this can become an issue when nutrients lie dormant creating buildup in the bottom of the tank. Mixers are available for larger tanks and highly recommended to keep water circulating and consistently mixed. Clear and opaque tanks can allow UV rays to penetrate into liquid fertilizers causing algae and organic buildup.
- **Bags:** Granular fertilizers and soil amendments are susceptible to moisture absorption. Growers should make an effort to reduce longterm inventory and shelter vulnerable nutrients. Bags of fertilizer should be stored off the ground on racks or pallets to keep floor water away from nutrients.



Plants

Media Types

Soil: Soil is a mixture of organic matter, minerals, gases, liquids and organisms. The most popular form of growing medium for indoor growers is soil, mostly because of its availability and ease of use. Soil is packaged in bags and is easy to move inside and use as needed in pots of all sizes. Many packaged brands of soil contain the nutrients desired for different plants at different stages of processing.

Rockwool: Formed from melting basaltic rock, rockwool is spun into cube and block form to provide a rooting substrate for plants. While rockwool can cause irritation to skin, eyes and lungs, it does provide a sterile growing environment for plants to thrive. There are no foreign nutrients, organic compounds or microbes so additional balanced nutrient solutions will be necessary to meet a plant's needs. Rockwool drains excess water quickly while storing small amounts of moisture towards the bottom of the cube, this unique property allows plants to retain water while proper amounts of oxygen allow the roots to breathe.

Substrate: While soil is the most common form of growing substrate, some growers prefer a hydroponic substrate composed of fibrous material that contains no nutrients or additives. A fibrous substrate requires all nutrients come from a water-based solution and are mostly used as architectural support for a developing plant. Similar to rockwool, substrates are filled with holes that allow water to quickly pass through and roots to breathe.

Coco Coir: Coco coir is a byproduct of coconut fiber and has been used in gardening since the 19th century. Fibers are mechanically removed and pressed into bricks, discs, coir pots or loose mulch. The piths, fibers and chips provide plenty of room for roots to grow and have a neutral pH range of 5.2-6.8. The Coco Coir medium provides antifungal properties and repels pests making it a very easy medium to grow in.



Bench Types

Bench Types: Bench sizes range from 4' - 8' wide and can be custom built for any length, 40-70' is the average length of a table. Lengths are limited mostly do to structural restraints in a facility or irrigation, HVAC and lighting specifications.

- **Rolling Benches:** Rolling benches make the best use of space by eliminating aisles in between tables and trays, trays or benches can be moved out of the way to maintain plants and the irrigation system. The ability to put all the trays together with no aisles also helps centralize the grow light spectrum over the plants.
- **Fixed Table:** A fixed table is going to lack the mobility of a rolling bench but can be built much larger. Many fixed tables have wheels to reposition when necessary but for the most part these tables are going to stay in the same place for the life of the operation.
- **Rolling Racks:** For smaller plants and propagation trays, a series of shelves are used with racks that roll out for inspection and trimming. Racking systems come with wheels or can be mounted to the floor to maximize room height.

Growing Practices

There are many different options when it comes to growing plants indoors and determining which to choose from is going to come down to available space, water source and ideal plant size. A few popular options are defined below.

- **Pots:** The use of pots allow growers to control their soil types and nutrient usage. Pots range in sizes from 1 to 20 gallons for indoor use and help to protect root systems from harmful UV rays. With indoor environments the ability to move plants from one place to another is sometimes crucial, pots allow growers to move and adjust plants when necessary.
- **Table:** Elevating plants off the ground makes trimming easier, brings light sources closer to canopies and allows water to drain into basins or secondary water catchments.
- **Troughs:** Similar to flood watering, troughs allow root systems to sit in basins of water while providing a protective coverings in a trough pattern to protect roots from drying up under indoor lights.
- **Vertical:** For maximum yield and return on investment, growing within a small space can involve building vertically. Fortunately for growers the indoor market has developed many pre-made options to grow plants in tiers or levels - by stacking shelves. Challenges can involve providing adequate lighting to plants and displacing water from tier to tier but the ability to grow vertically can produce great clones and smaller plants.

Plants Per Room

This can vary greatly depending on the growing or cultural practice. Having sufficient supply of moms to produce clone-stock is dependent on harvest schedules.

Common density for flower rooms is 1 plant per square foot but is extremely variable.

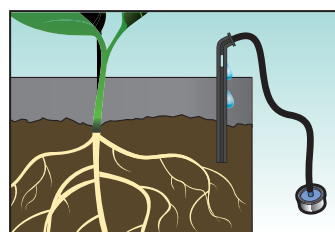
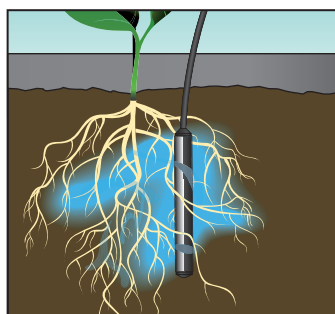
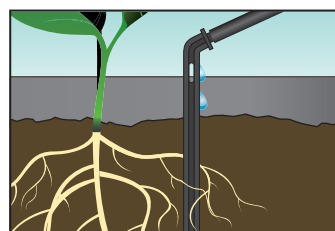
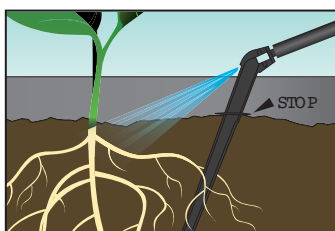


Irrigation

Emission Types

Delivering water to the plant is accomplished by using an emission device of some sort, without such a device water would drain out at an unpredictable, wasteful rate. Where and how irrigation water is distributed is attributed to the chosen point source emitter or watering stake device.

- **Point Source Emitter:** JAIN's point source emitter of choice is the ClickTif pressure compensating button emitter. Available in .5, 1, 2 and 3 GPH flow types and with a tapered or barb connection type. 1/4" tubing can be connected to utilize the pressure compensating aspect of the emitter while not being reliant on the emitters installation location. In addition to the 1/4" tubing lead a non-PC stake can be installed on the tubing's opposite end to move water deeper into the plant's media. Click on manifolds in single, dual and 4-way help to distribute water away from the emitter creating multiple connections for non-PC stakes.
- **Mini-Pepline:** For slower application rates and larger pot sizes, 1/4" emitterline can be used as a smaller version of a tree ring. 1/4" emitterline is not regulated therefore tubing must be attached to a PC manifold or emitter.
- **Flood:** Irrigation system restraints, water windows and sometimes a plants preferred watering type, flood watering is pretty self explanatory. While not the most efficient use of water; flood watering is one of the worlds most popular forms of irrigation. Presuming an operations groundwater or water supplier can provide the water needed to flood water - ideally growers are leaning away from this practice.
- **Multi-Port Manifolds:** With larger operations or projects with higher plant counts it can be difficult to provide lines to every pot, this is where a manifold with multiple connections is used. Manifolds are manufactured with 4-way and 8-way connection options and are offered in a pressure compensating and non-presuure compensating model. Manifolds typically come in different flows as well, the Octa-Bubbler is available in 2, 6, 10 and 20 GPH.



Irrigation

Ideal Water Amounts

Each plant has an ideal amount of water it needs to maintain optimal health, growing plants inside can make calculating K factors and plant demand difficult. Plants also demand an equal share of sunlight to process the water and nutrients being dealt by the irrigation system. A plants demand is measured by a K factor which can be referenced in most almanacs or reference material. Growers must also factor in the water that is leaving a plant through evapotranspiration, or the plant essentially sweating. This sweating or ET produces a nutrient and water deficit that must be met with consistent watering throughout a plants grow cycle.

In addition to a plants demand, the irrigation system components have an accuracy measurement of their own. Most overhead sprinklers are referred to with a precipitation rate, or precip rate. This precip rate lets a grower know how accurately the chosen emission devices are delivering water to a plant, landscape or tree. If all plants are receiving the same amount of water throughout a system of emission devices the system has deemed "matched precipitation". As in most of irrigation and growing keeping things consistent always makes design, maintenance and production more efficient.

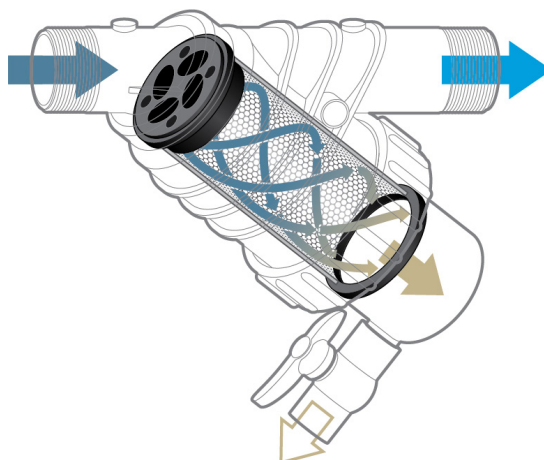
Plant Type	Plant Factor
Tree, Shrubs, Vines, Groundcovers (woody plants)	0.5
Herbaceous Perennial Plants	0.5
Desert Adapted Plants	0.3
Annual Flowers & Bedding Plants	0.8
General Turfgrass Lawns, cool-season (tall fescue, Ky. bluegrass, rye, bent)	0.8 ^{2, 3}
General Turfgrass Lawns, warm-season (bermuda, zoysia, St, Augustine, buffalo)	0.6 ^{2, 3}
Home Fruit Crops, Deciduous	0.8 ²
Home Fruit Crops, Evergreen	1.0
Home Vegetable Crops	1.0 ²
Mixed Plantings	<i>PF of the planting is that of the plant type present with the highest PF</i>

Irrigation

Filtration

Indoor operations come with an associated risk and reducing liability goes into every component selection. When irrigating indoors this is no different, an ideal irrigation system delivers the minimum amount of water to a plant, smaller amounts of water means smaller orifices delivering water. To eliminate unnecessary maintenance and provide plants with the consistent amount of water needed to thrive; filtration is necessary at the primary water connection point and at an individual zone valve level.

- **Main Line Filtration:** Main-lines move all the water needed for distribution and therefore come in contact with more unsuspecting contaminants than any other part of the irrigation system. To reduce the introduction of debris that can be pulled up from an aquifer or reservoir, build-up in a tank or from dirty utility lines after infrastructure repairs a screen filter is recommended.
- **Zone Filtration:** Indoor systems are broken up into stations or hydro(zones) to control water more precisely and to once again eliminate the amount of water that can be lost in a flood event. Zone valves are typically 3/4" - 2" and require the same size Y-filter installed on the secondary side of the valve. The combination of primary filtration at the water source and individual zone valve filtration will insure emission devices and propagation sprinklers do not clog.
- **Steel Screen Filters and Disc Filters:** Larger systems will require a filter larger than 2"; for burst protection and general efficiency to the flow path a steel filter is used on these systems. Steel screen filters are used when debris in the water supply can be an issue and disc filters are used when organics build up in tanks or reservoirs. Algae and organic growth is easier to clean off of the removable discs as opposed to scraping off of a steel filter.



Flushing to Minimize Maintenance

Along with proper primary filtration, flushing on the secondary side of tape and tubing is equally important. Debris caught in the filter will ideally have a path to freedom out of the end of a lateral line. While manual flushing is always an option we recommend a combination auto flush and air valve on the end of each lateral to reduce potential clogging. Flush valves are available with a barb or 1/2" pipe thread for direct tape or tubing installation.

Larger systems will require an air vent of some sort to release air when the system is charging and shutting down. Clogging in emitters is typically caused by air turbulence in the lines not necessarily debris in water. Reducing excessive air in lines as quickly as possible will help eliminate clogging.

- **Manual Flush Valves:** Manual on/off valves are a low cost alternative to a more controlled flushing. Available in glueable form or standard fitting connection types this type of valve should be used sparingly and installed where water displacement is not an issue.
- **Automatic Flushing:** Allowing a system to flush for a brief moment upon activation is an easy way to insure a reduction in clogging. Simple globe designed flush valves can be installed at the end of a zone and require little to no maintenance through the life of the product. Flush valves of any type will produce water that needs to be disposed of or repurposed. Taking this into account a drain can be setup to collect valuable water for testing or simple avoiding a potential slip and fall incident.



Irrigation

Drain Water

Larger grow operations will have irrigation water that needs to be contained for reuse or disposed of. While the ideal irrigation system does not produce too much run off there will still be the need to flush a system and the water will need to be taken into account. When necessary growers may choose to reuse run off water to maximize resources but typically drain water is simply disposed of.

- **Reuse and Disposal:** Reservoirs or basins, similar to the container growers use in the mixing or pumping process, are used to contain run off water from an irrigation system. Run off water will not contain much of the vital nutrients initially introduced through the irrigation system and for this reason run off water is typically used for purposes beyond plant irrigation, cleaning, flushing irrigation system etc. If non-organic chemicals are used in a system, water will need to be contained and disposed of according to local utility disposal policies.
- **Blending Options for Reuse:** The first step in the reuse of irrigation water is testing. Identifying acid levels will help growers identify what nutrients and additives need to be reintroduced to irrigation water to insure proper feedings going forward. Identical to the steps taken in the initial distribution of water, reused water will need to be cared for to reduce build up that can clog emission devices.
- **Treatment Types:** The option to reuse irrigation water must include the ability to treat and disinfect.
 - Chemical treatments such as hydrogen peroxide or peracetic acid include inline injection, testing, and recirculation injection to maintain desired disinfection targets.
 - Ultrafiltration involves a high filtration rate through membranes to remove pathogens.
 - Ultraviolet filters combine a fine filter with UV light to obtain target kill rates of pathogens.

Irrigation

Sizing a Pump for an Indoor Irrigation System

Determining the minimum and maximum desired flowrate for a system can be one of the biggest challenges in a indoor facility design. Pumps operate on a curve and have limitations to their low and high ends. Running a single bench versus an entire room calls for a separate pumping systems. Adding Variable Frequency Drives allows pumps to operate in a wider range while maintaining the required pressures, but it is still critical to consider the day to day cultivation practices when sizing pumping systems.

KEY ITEMS TO CONSIDER

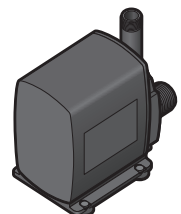
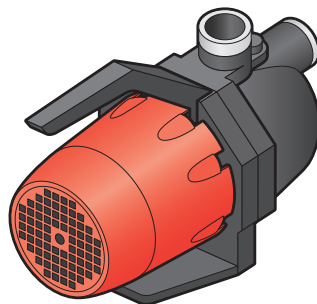
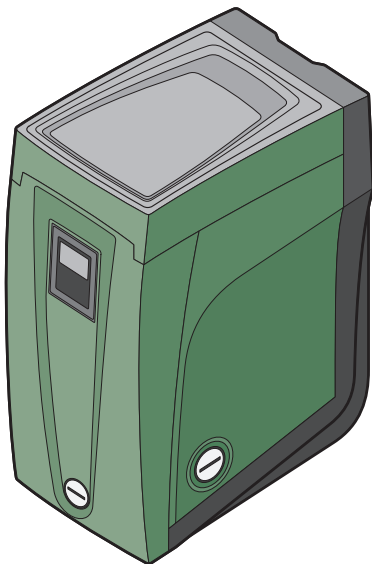
Water source GPM (Gallons Per Minute): Once available flow is determined it will be easier to figure out how much tape, emitterline or manifolds can be installed on a single control valve.

Hydro-Zoning: The main reason systems are separated into stations or Hydro "Zones" is to maximize available water and pressure in a system. Separating a system into zones will also help avoid catastrophic irrigation failure like a break.

PSI: Indoor irrigation systems typically require smaller amounts of water and low amounts of pressure. Emission devices do not typically require more than 45 psi to push water out. It is the combination of available flow (GPM) and pressure (PSI) that will help in pump sizing.

Determining Demand: For example, if 12" emitter spacing is used and a 1GPH flow emitter is chosen the total demand of water per 100' will be roughly 120 GPH or 2 GPM. Valve and filter size will be a direct result of this flow demand total. Sometimes it's easier to work backwards and calculate how many feet of tape or emitterline each row will require, if the system has 20GPM, then a grower knows there is 1000' of tape supply available.

Friction Loss: Once available water supply is determined, the system will need energy, or "pressure", to move water through the distribution pipes. While every elbow, tee and coupling eat up energy, nothing eats up pressure more than friction loss. Friction loss is the amount of drag pipe has in it's inner walls.



Irrigation

Mainline Design

Automating your irrigation system is not only going to greatly reduce labor expenses but a consistent water schedule is going to lead to a healthier crop.

- **Single Mainline:** A single mainline allows a grower to use one point of connection for a water supply and fertigation injection. One flow sensor is enough to monitor for breaks and provide reporting but there is an associated risk involved in the event of a break. Upon shutdown all zones are now rendered idle until the repair is made.
- **Multiple Mainlines per Zone:** Having multiple mainlines is sometimes necessary when a system is pulling from multiple water supplies or the grower determines a separate mainline is needed for the introduction of nutrients. While this will make it more difficult to find an automating controller to monitor multiple points of connection it will allow a grower to create a fail safe in the chance of a break or interruption in the primary water source.

Hydrozoning

After determining how much water the supply can provide, a grower can start to think about how many emission devices and valves are going to be a part of the system. While friction loss needs to be taken into account maximum consideration needs to be taken into account when determining how large each hydrozone should be.

- **Valve Configuration and Installation:** Valves will eventually need maintenance and replacement, planning in advance will make these processes that much easier. Consider future access and space restraints when choosing a location to mount valves and valve manifolds. Zone valves should include a pressure regulator and filter, the combination of these three components will require roughly 24" in lateral space. Most of the time installers will mount these assemblies to the wall so they are out of the way but available for servicing. Irrigation valves have NPT (Nominal Pipe Threading) or MPT (Male Pipe Threading) and range in size from 3/4" - 2". A popular 1" globe valve will allow 2-18 GPM to pass through with minimal pressure and flow loss. While smaller valves may not move substantial amounts of water - practicing this method will greatly reduce the amount of water lost during a break event.
- **Determining How Many Emission Devices:** Once a valve size has been determined an installer is now limited to the amount of water the zone valve can provide. A 1" globe valve with 10 gallons of water moving through it every minute can supply: (500) 1 GPH Click Tifs = 8.3 GPM
- **Determining How Much Tubing and Pipe:** There is no use in providing more water or pressure to a zone than needed, keeping pipe sizes down does reduce water supply but also reduces the expense of larger pipe diameters. Installers take multiple approaches to this aspect of irrigation design, some work from valve towards emitter and some work from emitter back to the valve. For simplicity we'll explain how to size a zone from valve to emitter. As determined above we have 8.3 GPM of water needed to supply the Click Tifs with the demand needed to emit accurately. In addition to emission component demand water and pressure are being lost as they move about the system. By referencing a Friction Loss Chart and emission types flow demand a total system demand can be determined. This total demand will need to be a volume the zones valve can handle, the combination of the correct size valve and right amount of emitters will stabilize a system and provide maximum efficiency while reducing damage brought to components by overwhelming design.

Irrigation

Controlling an Irrigation System

Automating an irrigation system is going to make consistent watering much easier and water management is of utmost importance when creating fertilizer and water budgets. Most valves operate with a 12V DC solenoid for battery and solar powered activation points or 24VAC solenoids when 110 is available at the controller. Regardless of solenoid type there is an automation solution for both solenoid options at different price points.

KEY ITEMS TO CONSIDER

- Is 110V available for a centralized controller?
- If pulling from reservoirs a Master Valve will be necessary to control all water coming out of tanks. This will also work as a connection point for a flow sensor.
- If the project is remote, a site manager will want to keep tabs on pre and post filter pressure and overall break control which will use the above-mentioned flow sensor.
- The systems JAIN offers can be operated from a smart device while more complex scheduling and monitoring are typically done with a computer.

110V SMART CONTROLLER OPTION

- Using real time ET measurements calculated hourly, plus predictive analytics for future weather, the SmartBox is an excellent choice. The Smart Box uses cloud based software to produce a scientific schedule based on user inputted site data. List Price: \$2600 - \$4100 depending on station count.
- Add a flow meter for comprehensive reporting and water budgets.
- User must have knowledge of the following site variables: soil type, grade, precip rate, distribution uniformity of emission devices, sun exposure and plant type.
- For smaller applications the HermitCrab2 will connect to most popular controllers and provide the same water managing tools as its bigger brother the SmartBox. List Price: \$1,250 with flow adapter.



General

Certified Design

It's important to choose a partner who has the industry experience and qualifications for proper irrigation design. Irrigation systems differ from many other trades in that they can vary dramatically from site to site. The systems must be designed to accommodate current growing practices along with any future potential changes. The Irrigation Association has several certification programs. Also, choosing a licensed contractor for installation is extremely important.

NOTES

[illegible]



JAIN is a fully integrated global food / plant production company recognized by Harvard Business to be one of five global sustainability champions, the G-20 for lifting people out of poverty, and Fortune magazine for being a “Change the World Company.” Our irrigation manufacturing capabilities include everything from the pump discharge to the flush valve at the end of the lateral and everything in between. We lead the industry in manufacturing technology, owning both our extrusion and mold manufacturing equipment providers.

JAIN leads plant science research globally across a variety of food crops and is staffed with some of the world’s leading research scientists. With the Gandhi Library, JAIN now houses the leading collection of the world’s best plant science knowledge in a single facility. Our agronomic knowledge is integrated from our world class plant tissue culture operations through our food processing businesses. We research, educate, advance, manufacture, finance, propagate plants, and purchase produce for processing all in an effort to fulfill the JAIN mission:

“Leave This World Better Than You Found It”

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