Chemigation Equipment and Calibration

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Chemigation is the application of agricultural chemicals to cropland by injection into irrigation water before the water is applied to the field. Chemigation may be used with surface, sprinkler, and drip irrigation. Not all agricultural chemicals are approved for use in chemigation systems, and many are not suitable because they may harm an irrigation system or precipitate out and plug nozzles. *Always check the chemical label before use.* It will indicate if the chemical can be used in chemigation systems, how to use it, and on which crops.

Chemigation equipment

Basic equipment required for chemigation includes a chemical storage tank, metering and injection equipment, antipollution equipment, and the sprinkler or surface irrigation water application system. The chemical storage tank is located near the injection point. Large plastic storage tanks are furnished by agricultural chemical dealers for fertilizer. Smaller tanks, purchased with an on-board injection unit, are used for pesticides. The irrigation system from the injection point downstream will be no different with chemigation than without chemigation because the backflow prevention equipment is upstream of the chemical injection point.

Backflow prevention equipment

One essential of chemigation is backflow prevention (preventing treated irrigation water from flowing back into the water source). This is true for both surface and pressurized systems. In surface systems, backflow can be prevented by injecting downstream of a break in the water, such as downstream of a check or weir (fig. 1). In pressurized systems, backflow in the mainline is typically prevented by either a chemigation valve (fig. 2) or a gooseneck pipe loop (fig. 3).

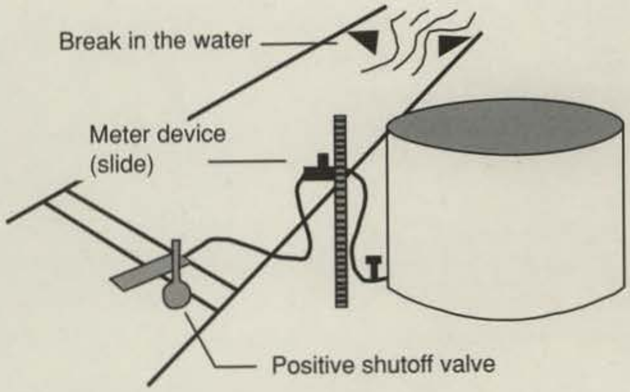

Figure 1. The proper location of the chemigation injection point in surface irrigation is downstream from a break (overfall) in the water. (Courtesy of Idaho Department of Agriculture)

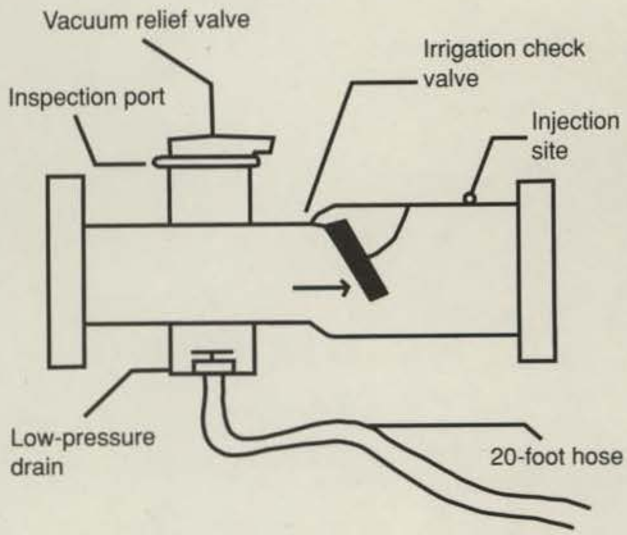

Figure 2. Chemigation valve requirements to prevent backflow and allow valve inspection. (Courtesy of Idaho Department of Agriculture)

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Additional protection against backflow is provided by an injection line check valve and interlock between the injection pump and irrigation system. The injection line check valve prevents backflow from the mainline into the chemical tank if the irrigation system stops. The interlock stops the injection pump if the irrigation system stops.

Chemigation valves are specially designed fittings that can be inserted into the pressure-side of a sprinkler or drip mainline. The valve includes all the elements needed to prevent backflow in the mainline: a system check valve, air/vacuum relief valve, inspection port, low-pressure drain, and 20 feet of hose. If properly installed, this type of valve, along with an injection line check valve and injection pump/irrigation system interlock, meets all chemigation backflow prevention requirements.

A gooseneck pipe loop (fig. 3) is another alternative to prevent mainline backflow. The dimensions listed in figure 3 are minimum requirements to ensure that mainline backflow does not occur. This alternative also requires an injection line check valve and injection pump/irrigation system interlock to meet all chemigation backflow prevention requirements.

Mainline size (inch)	Minimum air/vacuum relief valve size (inch)
2	1/2
3	3/4
4	1
5	1 1/4
6	1 1/2
8	2

Injection and metering equipment

On surface systems, the chemical is usually stored in a chemical tank located near the water break (overfall) in the water supply ditch. Calculate the storage capacity of the tank per inch of height. Then determine the number of inches of drop in the liquid level in the tank to apply the proper amount of chemical.

The middle portion of the outlet hose is mounted on a support at the level where outflow from the tank should stop. The end of the hose is placed in the ditch *downstream* from the break in the water. This arrangement creates a siphon that stops chemical flow when the liquid in the tank drops to the hose support level (fig. 1). The chemical flows from the tank by gravity; no electric power is needed.

A water-actuated valve on the end of the hose allows flow from the tank when water is in the ditch and stops flow if water flow in the ditch stops. Another valve on the hose can be used to control the flow rate from the tank to ensure that the chemical is injected during the proper portion of the advance phase of irrigation.

A check valve in the chemical delivery line is not required if the end of the hose is not submerged in ditch water. Positive displacement pumps can also be used but will require an interlock to stop the pump if flow in the ditch stops and a timer to run the proper amount of chemical for that set and then to shut the pump off.

On pressurized (sprinkler or drip) systems positive displacement piston and diaphragm pumps are the most-used chemigation injection pumps. If electricity is present, the pump can be powered by a single-

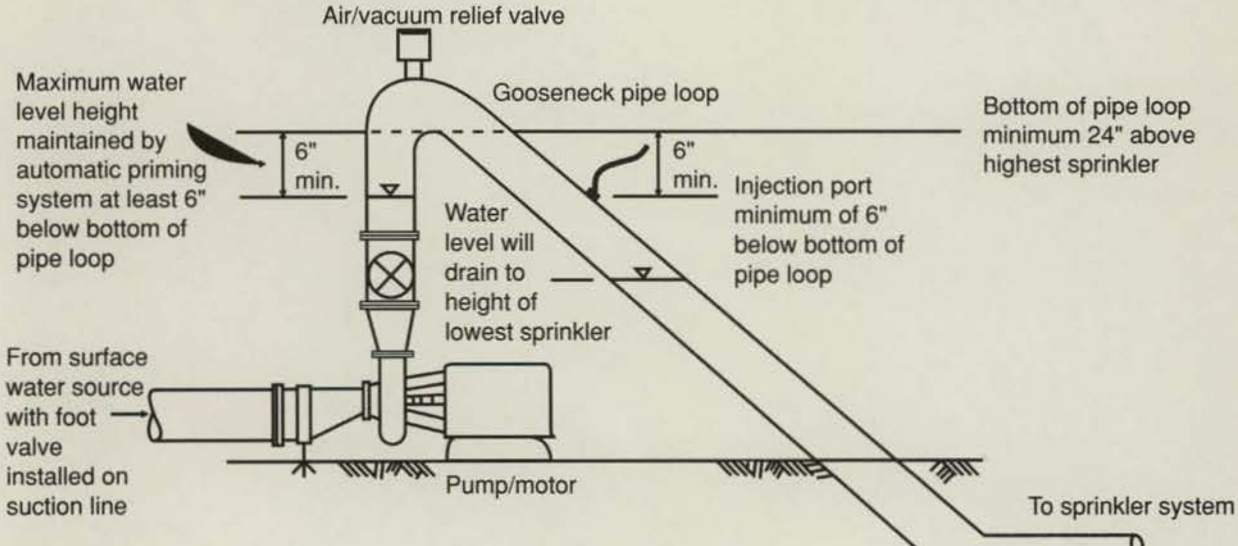

Figure 3. EPA-approved gooseneck pipe loop to prevent backflow (From *Chemigation in the Pacific Northwest*, PNW 360, 1992, by W. L. Trimmer, T. W. Ley, G. Clough, and D. Larsen)

or variable-speed electric motor. If no electricity is present, a small internal combustion engine is coupled to the pump to drive it.

The pump must be adjusted to give the proper chemical flow rate. On piston pumps, this is done by stopping the pump then increasing or decreasing the length of the piston stroke. The flow rate from a diaphragm pump can be changed while it is running, usually with a micrometer-type adjusting device. This makes calibration faster and easier.

Chemigation calibration

The goal in managing a chemigation system is to apply the correct amount of chemical at the correct location. This involves proper chemigation equipment calibration to ensure the correct amount of material is applied and proper irrigation system management to avoid moving the material too deep.

Chemigation calibration: Center pivots

Because the center pivot lateral is moving almost continuously, the chemical is injected continuously for the course of one irrigation pass. All water applied during the pass contains the chemical, and chemicals that move readily with the water in the soil should be nearly uniformly distributed throughout the depth of wetting.

Chemigation equipment calibration for center pivots involves determining the number of acres covered per minute and then determining how much chemical to add per minute for the desired application rate. This procedure is broken down into six basic steps:

1. Calculate the circumference of the last wheel track (ft)
2. Calculate the irrigated area (acres)
3. Calculate the system rate of travel (ft/min)
4. Calculate the time for one revolution (min)
5. Calculate the acres treated per minute (acres/min)
6. Calculate the chemical injection rate (gal/min)

Example 1. A center pivot with endgun not operating is to apply 30 units of N per acre (30 lb/acre) as 32% urea ammonium nitrate (uran), which contains 3.54 lb N/gal. Distance to the outer tower is 1,265 feet, and the overhang is 35 feet. The outer tower was found to travel 150 feet during a 1-hour period when running at the chemigation speed. Determine the required injection rate in gpm and liters/min.

Step 1: Calculate the circumference of the last wheel track (ft).

Circumference = (2)(3.1416)r,

where r = distance to outer tower or 1,265 ft.

$$\text{Circumference} = (2)(3.1416)(1{,}265) = 7{,}948 \text{ ft}$$

Step 2: Calculate the irrigated area (acres).

Area = $3.1416R^2$, where $R = r$ + overhang in feet.

$$= 3.1416(1{,}265 + 35)^2$$
$$= 3.1416(1{,}300)^2$$
$$= 3.1416(1{,}690{,}000)$$
$$= 5{,}309{,}304 \text{ ft}^2$$

but 1 acre = 43,560 ft^2, so

$$\text{Area} = 5{,}309{,}304 \text{ ft}^2\left(\frac{1 \text{ acre}}{43{,}560 \text{ ft}^2}\right)$$
$$= 122 \text{ acres}$$

Step 3: Calculate the rate of travel of the outer tower (ft/min).

$$\text{Outer tower travel rate} = \frac{150 \text{ ft}}{60 \text{ min}} = 2.5 \text{ ft/min}$$

Step 4: Calculate the time required for one pivot rotation (min).

$$\text{Time/revolution} = \frac{\text{circumference (from step 1)}}{\text{outer tower travel rate (from step 3)}}$$
$$= \frac{7{,}948 \text{ ft}}{2.5 \text{ ft/min}}$$
$$= 3{,}179 \text{ min or } 53 \text{ hours}$$

Step 5: Calculate the acres treated per minute.

$$\text{Acres treated/min} = \frac{\text{acres treated}}{\text{min/revolution}}$$
$$= \frac{122 \text{ acres}}{3{,}179 \text{ min}}$$
$$= 0.03838 \text{ acres/min}$$

Step 6: Calculate uran injection rate (gal/min)

$$\text{Injection rate (gal/acre)} = \frac{\text{application rate}}{\text{lb N/gal uran solution}}$$
$$= \frac{30 \text{ lb N/acre}}{3.54 \text{ lb N/gal}}$$
$$= 8.47 \text{ gal/acre}$$

$$\text{Injection rate (gal/min)} = (8.47 \text{ gal/acre})(0.03838 \text{ acre/min})$$
$$= 0.32 \text{ gal/min}$$

or, since 1 gallon = 4 quarts or 128 fluid ounces,

Injection rate (quarts/min)

$$= (0.32 \text{ gal/min})(4 \text{ quarts/gal})$$
$$= 1.3 \text{ quarts/min}$$

Injection rate (fluid ounces/min)

$$= (0.32 \text{ gal/min})(128 \text{ ounces/gal})$$
$$= 41 \text{ fluid ounces/min}$$

Injection rate (liters/min)

$$= (0.32 \text{ gal/min})(3.785 \text{ liters/gal})$$
$$= 1.21 \text{ liters/min}$$

Therefore, set injection equipment to deliver 0.32 gal/min, 1.3 quarts/min, 41 fluid ounces/min, or 1.21 liters/min.

If an endgun is to be operating during part of the rotation, the injection rate must be increased to account for the additional area watered. Recalculate the injection rate, adding the effective endgun radius to the radius previously used in steps 1 and 2.

Chemigation calibration: Set-move (wheelline and handline) and solid set

In set-move systems, chemicals may be injected either continuously or in batch mode during some period of the irrigation. If injected continuously, all water applied during the irrigation contains the chemical. Therefore, any added chemicals that move readily with water in the soil should be nearly uniformly distributed throughout the depth of wetting.

Because of convenience and the types of pumps generally available, chemigation in set-move systems is generally done in batch mode. All chemical is added over a short period, usually about 30 minutes. If added near the beginning of the set, the chemical will be followed with regular irrigation water, which will tend to push it deeper into the soil. If added near the end, it will remain closer to the surface.

Chemigation equipment calibration for set-move systems involves determining the number of acres covered during each set and the amount of chemical to add per set. From this, the rate of chemical injection into the irrigation system can be determined so that the chemical is injected in a certain amount of time. This procedure is broken down into six basic steps:

1. Determine the area to be treated (acres).
2. Determine the desired amount of chemical to be applied based on label directions (lb/acre).
3. Determine the total amount of chemical required (lb or gal) by multiplying the treated area by the chemical application rate.
4. Determine the length of time, in minutes, during which injection will take place. Consider irrigation set length, water application rate, water applied with chemical, and chemical transit time in the system.
5. Determine the proper chemical mixture or proper volume of chemical solution.
6. Determine the injection rate and set the injection device to the proper flow rate.

Example 2. Four 1,200-foot-long wheellines are operated at the same time. Sprinkler spacing along each lateral is 40 feet, and laterals are moved 50 feet between sets. The system is to apply 30 units of N per acre (30 lb/acre) as 32% urea ammonium nitrate (uran). Uran solution contains 3.54 lb N/gal. Determine the required injection rate in lb/min and liters/min.

Step 1: Determine the treated area (acres).

$$\text{Area per wheelline} = \frac{(\text{length})(\text{lateral spacing})}{43{,}560 \text{ ft}^2/\text{acre}}$$
$$= \frac{(1{,}200 \text{ ft})(50 \text{ ft})}{43{,}560 \text{ ft}^2/\text{acre}}$$
$$= 1.38 \text{ acres/wheelline}$$

Since we have 4 lines, total area = 4(1.38)
= 5.52 acres

Step 2: Determine the desired amount of chemical to apply (units/acre).
Given: We want to apply 30 units/acre N as uran.

Step 3: Determine the total chemical required (lb).
Total required chemical = (total set area [from step 1]) (application rate [from step 2])
= (5.52 acres)(30 lb/acre)
= 165.6 lb N

Step 4: Determine injection time (hours).
For impact sprinklers in a wheelline setting, 15 minutes is the minimum injection time to give "uniform" application; 30 minutes is better. Therefore, select 30 minutes.

Step 5: Determine the total chemical solution volume required (gal).

$$\text{Total volume} = \frac{\text{total applied chemical (from step 3)}}{\text{lb N/gal uran solution}}$$
$$= \frac{165.6 \text{ lb N}}{3.54 \text{ lb N/gal}}$$
$$= 46.8 \text{ gal uran}$$

Step 6: Determine the injection rate (gal/min).

$$\text{Injection rate} = \frac{\text{total volume to be injected (from step 5)}}{\text{injection time (from step 4)}}$$
$$= \frac{46.8 \text{ gal}}{30 \text{ min}}$$
$$= 1.56 \text{ gal/min}$$
$$= 5.9 \text{ liters/min}$$

Therefore, set the injection equipment to deliver 1.56 gal/min or 5.9 liters/min.

Chemigation calibration worksheets for both center pivot and set-move systems are on pages 7 and 8. They contain an example calculation and room for you to do a calculation for your own system.

Irrigation management for effective chemigation

Chemigation timing

Effective chemigation requires a knowledge of soil moisture and of the application rate of the irrigation system. Manage irrigation water to avoid applying more water than the crop root zone can hold while applying enough water to ensure that the applied chemical moves to the correct depth. Excess water will leach water-soluble crop nutrients such as nitrogen below the crop root zone and cause the producer to use more chemical.

On the other hand, there have been a number of instances in southern Idaho where insufficient water was applied with a herbicide. As a result, the herbicide concentrated near the surface in a dry zone and did not activate. Weed control was very poor.

Determination of initial soil moisture in the surface 3 inches is critical when applying a herbicide that must be incorporated to a specific depth by water movement, particularly for soils with large water-holding capacities. If the soil is moist, the values for 35 percent depletion from table 1 would apply. For example, if the chemical is to be located in the top 3 inches and soil moisture before chemigation was 35 percent depleted (65 percent available soil moisture), 1 inch of water would wet 14 inches of a silt loam soil.

Because we want to wet the top 3 inches, we would apply 3/14 x 1 inch or 0.21 net inches of water. For a pivot with low-pressure drop nozzles and a typical application efficiency of 85 percent, we would need to apply a gross irrigation (the water we actually pump through the system) of 0.21/0.85 or 0.25 inches of water to fill the top 3 inches of soil to field capacity.

For dry conditions, where the top 3 inches may be near permanent wilting point (100 percent depleted), more water would be required to fill each of the top 3 inches. If the soil were at permanent wilting point (dry and powdery when you pour it from one hand to the other and having no visible moisture when squeezed), 1 inch of water would fill the top 5 inches of a silt loam soil. If we applied the same 0.25 inch gross irrigation, net irrigation to the soil would be 0.21 inches for an 85 percent application efficiency system. This would wet (0.21 inch/1.0 inch) x 5 inches wet per inch applied or 1.05 inches.

To wet the same 3-inch depth at this moisture content would take 3 inches desired/5 inches per inch applied or 0.6 inches net irrigation. With an irrigation efficiency of 85 percent, the gross amount to apply would be 0.6 inches/0.85 or 0.7 inches. This is considerably different from the 0.25 inches required for a moist soil! If we wanted to fill the top 3 inches of a 100 percent depleted (permanent wilting point) silt loam soil with a wheelline that has an application efficiency of about 65 percent with wind blowing, we would need a gross irrigation of 0.6 inches/0.65 or 0.92 inches!

Assumptions for examples 3 and 4. N moves with water downward through the soil profile. The majority of the N in set-move applications moves in a relatively thin layer, pushed downward by additional water. In reality, some water and N move deeper than calculated due to movement in worm holes, old root channels, etc., while some stays higher in the profile than calculated due to dispersion into slowly moving or stagnant pore water. The depth calculated then represents an average location for the majority of the applied N.

Example 3. A center pivot makes a 1 inch gross application per revolution. If application efficiency is 80 percent, then net irrigation is 0.8 inches. The N is continuously applied by the center pivot so the N is uniformly located throughout the entire depth of wetted soil. If the field is irrigated at 75 percent available moisture, how deep would you expect the N to move in a silt loam soil?

From table 1 with 75 percent available soil moisture (25 percent depleted), 1 inch of water will wet 20 inches of soil. Therefore, 0.8 inches of water will wet 16 inches of soil. The N is fairly uniformly distributed throughout this depth. If this is too deep, the pivot can be run faster to supply less water and wet a shallower depth per revolution.

Table 1. Depth (in inches) penetrated by a 1-inch net water application.

Moisture content (% depleted)	Sandy	Loam	Silt loam	Clay
25	48	28	20	22
35	34	20	14	16
50	24	14	10	11
75	16	9	7	7
100	12	7	5	5

Note: Average water-holding capacities (inches per foot) are as follows: sandy, 1.0; loam, 1.7; silt loam, 2.4; clay, 2.2.
Source: Adapted from *Chemigation in the Pacific Northwest*, Pacific Northwest Extension Publication 360.

Example 4. A wheelline system is applying N. Nozzle diameter is 9/64 inch, giving a system discharge of 4 gal/min/sprinkler at 50 psi. Nozzle spacing along the line is 40 feet, and spacing between sets is 50 feet. Sprinklers are operated for 11 hours with a 12-hour total set time. About 50 percent available soil water still remains in the soil when chemigation begins. To what depth would you expect N to move in a sandy soil if chemigation begins 30 minutes after the start of the set and occurs over a 30-minute period?

From a nozzle table or slide rule, gross application rate is 0.2 inches/hour. Application rate (inches/hr) may also be calculated as:

Application rate

$$= \frac{(\text{nozzle gal/min})(1\text{ft}^3/7.48\text{ gal})(12\text{ in/ft})(60\text{ min/hr})}{(\text{spacing on lateral})(\text{spacing between laterals})}$$

$$= \frac{(4\text{ gal/min})(1\text{ft}^3/7.48\text{ gal})(12\text{ in/ft})(60\text{ min/hr})}{(40\text{ ft})(50\text{ ft})}$$

= 0.192 in/hr or approximately 0.2 in/hr

If application efficiency is 65 percent, then the net application rate (water actually reaching the soil surface and soaking in) is 0.192 inch/hour x 0.65 or 0.125 inch/hour.

At 50 percent available water still remaining in the root zone, table 1 indicates that 1 inch of applied water will fill 24 inches of soil to field capacity. In 30 minutes, about 0.06 inch of water is applied, so the N will be distributed throughout a minimum thickness of 0.06 x 24 inches or about 1.4 inches. Chemigation will be followed by 10 hours of irrigation, which will apply 10 hours x 0.125 inches/hour or 1.25 inches of water. If 1 inch wets 24 inches, then 1.25 inches will wet the top 30 inches of the soil profile.

The N will then be mainly in the 30- to 32-inch depth—too deep for shallow-rooted crops like potatoes and almost too deep for grain. To keep the N closer to the soil surface in a sandy soil, it should be injected later in the set so that less water is available following chemigation to push it downward in the profile.

System flushing time

Following chemigation, the system should be operated for a period sufficient to flush any remaining chemical. Failure to do so can result in component corrosion, nozzle clogging, and freezing of valves by precipitated material.

Mainlines. Design velocity in most mainlines is about 5 ft/sec. Therefore, a general rule for minimum flushing time in minutes is pipeline length divided by 300. For example, a short slug of material should pass through a 900-foot pipeline in 900/300 or 3 minutes.

Set-move systems. For wheelline, handline, or solid set systems, allow a minimum of 30 minutes flushing time for a 1,300-foot line. For a 600-foot line allow at least 20 minutes. To determine an exact flushing time for your system with your nozzle size, inject a dye or food coloring at the injection point and record the time required for the dye to be flushed from the last nozzle on the line.

Center pivots. Flushing time is not an issue during mid-season when pivots run continuously. Since pivots are designed in many ways, flushing time in early or late season can best be determined by injecting colored dye and observing the time required for the dye color to clear the last nozzle.

Safety in Chemigation

- ✔ Inject colored dye with the chemical to show when chemicals are being applied.
- ✔ Keep chemicals out of irrigation ditches, off roads, and away from homes.

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Chemigation calibration worksheet

Center pivots

	Example	Your case
Inputs		
Distance to outer tower (r), ft	1,265'	
Overhang, ft	35'	
Outer tower rate of travel, ft/hour	150' in 1 hour	
Material to apply	32% N soln.	
Application rate, lb/acre, etc.	30 lb/ac	
Active ingredient, lb/gal	3.54	
Calculations		
1. Last wheel track circumference (C) $C = (2)(3.1416)r$	7,948'	
2. Irrigated area (A) $A = \frac{3.1416(r\text{+overhang})^2}{43{,}560}$	122 acres	
3. Outer tower travel rate (V_o) V_o = ft traveled/time in min	2.5 ft/min	
4. Pivot rotation time (T), min $T = \frac{C \text{ (from step 1)}}{V_o \text{ (from step 3)}}$	3,179 min (53 hr)	
5. Acres treated/min = $\frac{A \text{ (from step 2)}}{T \text{ (from step 4)}}$	0.03838 acres/min	
6. Injection rate (I_a), gal/acre $I_a = \frac{\text{material application rate}}{\text{lb active ingredient/gal}}$	8.47 gal/acre	
Injection rate (I_t), gal/min $I_t = I_a \times$ step 5	0.32 gal/min	

Chemigation calibration worksheet
Set-move or solid set

	Example	Your case
Inputs		
Lateral length (L), ft	1,200′	
Spacing between laterals (S), ft	50′	
Number of laterals/set (N)		
Material to apply	32% N soln.	
Application rate, lb/acre, etc.	30 lb/ac	
Active ingredient, lb/gal	3.54	
Calculations		
1. Irrigated area per lateral (A_l) $A_l = \frac{LS}{43,560}$	1.38 acres	
Irrigated area/set (A_s) $A_s = A_l N$	5.52 acres	
2. Application rate (from input information)	30 lb/acre	
3. Total chemical required (Wt), lb Wt = (chemical application rate) (A_s [from step 1])	165.6 lb N	
4. Injection time (T), min 30 minutes is minimum (use 30 minutes here)	30 min.	
5. Total solution volume $= \frac{Wt \text{ (from step 3)}}{\text{lb active ingredient/gal}}$	46.8 gal	
6. Injection rate (I_t), gal/min $I_t = \frac{\text{step 5}}{T}$	1.56 gal/min	

1/97 1,200

$1.50