2008

Using Chemigation Safely and Effectively: Calibration Workbook

[Published 2008]

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Using Chemigation Safely and Effectively

Calibration Workbook

University of Nebraska ─ Lincoln Extension Division

Institute of Agriculture and Natural Resources

and the

Nebraska Department of Environmental Quality

HOW TO USE THIS WORKBOOK

This booklet is designed to be used with the "***Calibration***" section of the Using Chemigation Safely and Effectively training DVD. The workbook examples correspond with the DVD presentation. During the presentation, you are encouraged to ask questions, and work through the calculations in this workbook and use it as a reference in the field.

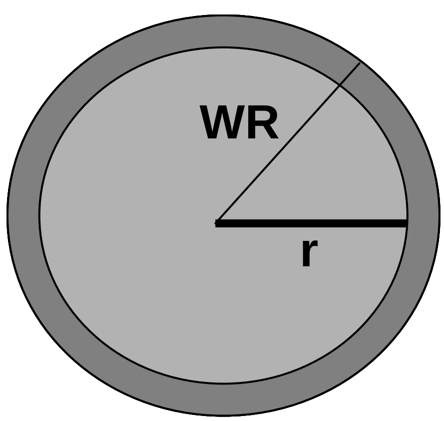
Example calculations are included for applying insecticides, and fertilizers through center-pivots. However, they represent the simplest situations of calibrating a center-pivot irrigation system. To calibrate other irrigation system types such as, a corner system or a system with intermittent use of an end gun, requires additional calculations. Equations for other system configurations are presented in the Chemigation Manual. Additional calibration problems are provided in Appendix I.

NOTE: Persons who use a calculator with a built-in pi (π) function to do the calculations may get slightly different answers from those given in the video and in this workbook.

Following are some equations and conversion factors you may need to properly calibrate a chemical injection device:

Circumference of the last wheel track	=	π x 2 x r
Wetted area of a center pivot	=	π x WR x WR
π	=	3.14
1 Acre	=	43,560 square feet
450 gpm	=	1.0 acre-inch per hour
1440 minutes	=	24 hours
1 gallon	=	128 ounces
3785 milliliters	=	1 gallon
2 pints	=	1 quart
4 quarts	=	1 gallon
1 gallon per hour	=	2.13 ounces per minute
1 gallon per hour	=	63 milliliters per minute

1 gallon of 28% UAN solution contains 2.98 lbs of nitrogen
1 gallon of 32% UAN solution contains 3.54 lbs of nitrogen



CALIBRATION

Calibration is a procedure to determine the amount of chemical to apply to a given area during a predetermined amount of time. For convenience - and accuracy - many chemical injection systems are sold with calibration tubes. Ordinarily it is a cylinder, graduated in units of volume and installed in the chemical injection system between the chemical supply tank and the chemical injection pump. The process can consist of up to 8 steps. Calibration requires a determination of the:

1. total area to be treated
2. volume of chemical applied per acre
3. total amount of chemical required
4. amount of solute to use, if needed
5. depth of water applied per acre
6. total treatment time required
7. chemical injection rate needed
8. adjustment of the chemical injection pump.

FERTILIZER EXAMPLE

Revolution Time – Full Circle:

Revolution time is the time necessary for the center-pivot to complete one revolution or chemical application. Revolution time is calculated in two parts. First calculate the circumference of the last wheel track. The formula for calculating circumference is 2 x π x r where π = 3.14 and r is the distance from the pivot point to the last wheel track (in this example, r = 1250 feet).

$$\text{Circumference of the last wheel track} = 2 \times \pi \times r$$

Substituting the numbers into the equation:

$$\text{Circumference of the last wheel track} = 2 \times 3.14 \times 1250 \text{ ft}$$

$$= \mathbf{7850\ ft}$$

The second step to calculate revolution time is to divide the circumference of the last wheel track in feet by the travel speed of the pivot in feet per minute **(earlier in the video, the travel speed was measured as 68 ft in 10 minutes or 6.8 ft/min at a percentage timer setting of 100%).**

$$\text{Revolution time} = \frac{\text{circumference in feet}}{\text{travel speed in ft/min}}$$

Substituting the numbers into the equation:

$$\text{Revolution time} = \frac{7850 \text{ ft}}{6.8 \text{ ft/min}}$$

$$= \mathbf{1154.4\ min}$$

Converting minutes to hours:

$$\text{Revolution time} = \frac{1154.4 \text{ min}}{60 \text{ min/hr}}$$

$$= \mathbf{19.2\ hours}$$

Total Acres Treated – Full Circle:

First you will need to calculate the number of acres under the center-pivot. If we assume that the wetted radius (R) of a center-pivot is 1300 feet and $\pi = 3.14$ we can calculate the area treated using the formula:

$$\text{Wetted area of a center pivot} = \pi \text{ x } WR^2$$
$$= \pi \text{ x } WR \text{ x } WR$$

The superscript 2 to the right of WR means to square the number by multiplying the number by itself.

Substituting the numbers into the equation:

$$\text{Wetted area of a center pivot} = 3.14 \text{ x } 1300 \text{ ft. x } 1300 \text{ ft.}$$
$$= 5{,}306{,}600 \text{ sq. ft.}$$

Convert area under the pivot to acres by dividing 5,306,600 sq. ft. by 43,560 sq. ft./acre.

$$\text{Wetted area Treated} = \frac{5{,}306{,}600 \text{ sq. ft.}}{43{,}560 \text{ sq. ft./acre}}$$

$$= \mathbf{121.8\ acres}$$

Volume Needed per Acre:

Suppose we want to apply 30 lbs of nitrogen per acre using 28% Urea-Ammonia Nitrate fertilizer (UAN). There are 2.98 pounds of nitrogen in a gallon of 28% UAN fertilizer and 3.54 pounds of nitrogen in a gallon of 32% UAN. To calculate the gallons of UAN needed per acre, divide the pounds of nitrogen to be applied per acre by the pounds of nitrogen in each gallon of UAN fertilizer.

$$\text{Amount of 28\% UAN fertilizer/acre} = \frac{\text{lbs of N desired per acre}}{\text{lbs. N/gallon}}$$

Substituting the numbers into the equation:

$$\text{Amount of 28\% UAN fertilizer/acre} = \frac{30 \text{ lbs N/acre}}{2.98 \text{ lbs N/gal}}$$

$$= \mathbf{10.1\ gal/acre\ of\ 28\%\ UAN}$$

If 32% UAN fertilizer is used the calculation becomes:

$$\text{Amount of 32\% UAN fertilizer/acre} = \frac{30 \text{ lbs N/acre}}{3.54 \text{ lbs N/gal}}$$

$$= \mathbf{8.5\ gal/acre\ of\ 32\%\ UAN}$$

Total Volume of Fertilizer Needed:

To determine total gallons of fertilizer needed, multiply the gallons of nitrogen needed per acre (10.1 gal/ac) by the area treated (121.8 acres).

Total fertilizer needed = acres treated x rate per acre

Substituting the numbers into the equation:

Total fertilizer needed = 121.8 acres x 10.1 gal/acre

= **1230 gals**

Water Application Depth:

Suppose the pesticide label for a herbicide requires the application of 0.75 inches of irrigation water. We assume that our center pivot has a water application efficiency of 85%. For a net application of 0.75 inches, the amount of water required is determined by dividing the net irrigation depth required by the water application efficiency (decimal).

$$\text{Depth water to be pumped} = \frac{\text{net of water requirement}}{\text{estimated application efficiency}}$$

Substituting the numbers into the equation:

$$\text{Depth water to be pumped} = \frac{\text{0.75 inches}}{\text{0.85 application efficiency}}$$

= **0.88 inches**

Thus, 0.88 inches of water must be pumped to achieve a net irrigation depth of 0.75 inches.

Total Water Pumped:

To determine the total acre-inches of water applied, multiply the gross application depth by the total acres treated as determined previously (121.8 acres).

The total volume of water to be pumped can be calculated using the formula:

Total water to be pumped = Depth to be pumped x acres treated

Substituting the numbers into the equation:

Total water to be pumped = 0.88 in x 121.8 acres

= **107.2 acre-inches**

Irrigation Rate:

Next, determine the pumping rate in acre-inches per hour. First divide the pumping capacity by the constant 450 (450 gpm is equivalent to one acre-inch per hour). Let's assume that our irrigation pump delivers 750 gpm.

$$\text{Acre-inches/hour} = \frac{\text{Pump flow rate in gpm}}{\text{450 gpm per ac-in per hour}}$$

Substituting the numbers in the equation:

$$\text{Acre-inches/hour} = \frac{\text{750 gpm}}{\text{450 gpm/ac-in per hour}}$$

$$= \textbf{1.7 acre-inches / hour}$$

Total Treatment Time:

Now determine the revolution time to apply 0.88 inches of water by dividing the total water volume in acre-inches (107.2 acre-inches) by the pump flow rate in acre-inches per hour.

$$\text{Revolution time} = \frac{\text{acre-inches of water needed}}{\text{acre-inches of water pumped/hr}}$$

Substituting the numbers in the equation:

$$\text{Revolution time} = \frac{\text{107.2 acre-in}}{\text{1.7 acre-in/hr}}$$

$$= \textbf{63.1 hours}$$

Pivot Speed Setting:

To set the percent timer on the center pivot to get a revolution time of 63.1 hr, we must refer back to the example of the 100% timer setting where we calculated a revolution time of 19.2 hours. Divide revolution time for the pivot at 100% (19.2 hours) and divide by the revolution time needed to apply 0.88 inches (63.1 hours).

$$\text{Estimated percent timer setting} = \frac{\text{Revolution time at 100\% setting}}{\text{desired revolution time}}$$

Substituting the numbers into the equation:

$$\text{Estimated percent timer setting} = \frac{\text{19.2 hours}}{\text{63.1 hours}}$$

$$= \textbf{30\%}$$

Set the timer at this setting and record the speed of travel. Confirm by calculating revolution time with the measured speed of travel. Modify the timer setting until correct revolution time is achieved.

Injection Rate in Gallons Per Hour:

For our fertilizer example, we calculated the total chemical needed at 1230 gals of 28% UAN fertilizer To calculate the chemical injection rate delivered by the injection device in gallons per hour we divide the total fertilizer needed by the revolution time.

$$\text{Injection rate} = \frac{\text{Total gallons needed}}{\text{Revolution time}}$$

Substituting the numbers into the equation:

$$\text{Injection rate} = \frac{\text{1230 gals of fertilizer}}{\text{63.1 hours}}$$

$$= \mathbf{19.5\ gal/hour}$$

Injection Rate in Ounces per Minute:

The final step in the calibration process is to convert the injection rate in gals/hour to match the units on the calibration tube in either ounces/minute or millimeters per minute.

Converting gallons per hour (gph) to ounces/minute (oz/min) we multiply the injection rate in gallons per hour (19.5 gals/hr) by the equivalent number of ounces per minute ***([128 oz/gallon ÷ 60 minutes per hour]*** or 2.13 oz/min):

$$\text{oz/min} = \text{19.5 gals/hr} \times 2.13$$

$$= \mathbf{41.5\ oz/min}$$

Injection Rate in Milliliters per Minute:

If the calibration tube is in milliliters we must convert gallons per hour (gph) to millimeters/minute (ml/min). Using the fertilizer example, multiply 18.9 gals/hr by the equivalent number of milliliters per minute ***([3785 ml/gallon ÷ 60 minutes per hour]*** or 63 ml/min).

$$\text{ml/min} = \text{19.5 gals/hr} \times 63$$

$$= \mathbf{1{,}228.5\ ml/min}$$

PESTICIDE EXAMPLE

Total Chemical Required:

Suppose you want to apply an insecticide at the recommended rate of 2 pints of pesticide plus 2 pints of crop oil per acre to a 122-acre center pivot. Since there are 2 pints in a quart, the equivalent volume is 2 quarts of the pesticide + oil combination.

$$\text{Total pesticide + oil needed} = \text{Acres treated} \times \text{Rate per acre}$$

Substituting the numbers into the equation:

$$\text{Total pesticide +oil needed} = 122 \text{ acres} \times 2 \text{ quarts/acre}$$

$$= \mathbf{244 \text{ quarts of pesticide plus crop oil}}$$

The insecticide label calls for the pesticide mixture to be diluted with fresh water in a ratio of 7 parts fresh water to 4 parts pesticide mixture. The total amount of water needed can be calculated by multiplying the amount of pesticide mixture required by 7/4.

$$\text{Total water needed} = \frac{244 \text{ quarts} \times 7 \text{ parts fresh water}}{4 \text{ parts pesticide mixture}}$$

$$= \mathbf{427 \text{ quarts of water}}$$

Adding the volume of fresh water to the volume of pesticide mixture yields a total volume of 671 quarts.

Converting quarts to gallons for the water and pesticide mixture:

$$\text{Total pesticide mixture needed} = \frac{671 \text{ qts}}{4 \text{ qts/gal}}$$

$$= \mathbf{167.75 \text{ gals of solution}}$$

The pesticide label for the insecticide also recommends the application of 0.30 inches of irrigation water. We assume that our center pivot has a water application efficiency of 85%. For a net application of 0.30 inches, the amount of water required is determined by dividing the net irrigation depth required by the water application efficiency (decimal).

$$\text{Depth water to be pumped} = \frac{\text{net of water requirement}}{\text{estimated application efficiency}}$$

Substituting the numbers into the equation:

$$\text{Depth water to be pumped} = \frac{0.30 \text{ inches}}{0.85 \text{ application efficiency}}$$

$$= \mathbf{0.35 \text{ inches}}$$

Thus, 0.35 inches of water must be pumped to achieve a net irrigation depth of 0.30 inches.

Total Water Pumped:

To determine the total acre-inches of water applied, multiply the gross application depth by the total acres treated (assume = 122 acres).

The total volume of water to be pumped can be calculated using the formula:

Total water to be pumped = Depth to be pumped x acres treated

Substituting the numbers into the equation:

Total water to be pumped = 0.35 in x 122 acres

= **43.1 acre-inches**

Irrigation Rate:

Next, determine the pumping rate in acre-inches per hour. First divide the pumping capacity by the constant 450 (450 gpm is equivalent to one acre-inch per hour). Let's assume that our irrigation pump delivers 725 gpm.

$$\text{Acre-inches/hour} = \frac{\text{Pump flow rate in gpm}}{\text{450 gpm per ac-in per hour}}$$

Substituting the numbers in the equation:

$$\text{Acre-inches/hour} = \frac{\text{725 gpm}}{\text{450 gpm/ac-in per hour}}$$

= **1.6 acre-inches / hour**

Total Treatment Time:

Now determine the revolution time to apply 0.35 inches of water by dividing the total water volume in acre-inches (43.1 acre-inches) by the pump flow rate (1.6 acre-inches per hour).

$$\text{Revolution time} = \frac{\text{acre-inches of water needed}}{\text{acre-inches of water pumped/hour}}$$

Substituting the numbers in the equation:

$$\text{Revolution time} = \frac{\text{43.1 acre-in}}{\text{1.6 acre-in/hr}}$$

= **26.9 hours**

Pivot Speed Setting:

To set the percent timer on the center pivot to get a revolution time of 26.9 hours, we must refer back to the example of the 100% timer setting where we calculated a revolution time of 19.2 hours. Divide revolution time for the pivot at 100% (19.2 hours) and divide by the revolution time needed to apply 0.35 inches (26.9 hours).

$$\text{Estimated percent timer setting} = \frac{\text{Revolution time at 100\% setting}}{\text{desired revolution time}}$$

Substituting the numbers into the equation:

$$\text{Estimated percent timer setting} = \frac{\text{19.2 hours}}{\text{26.9 hours}}$$

$$= \mathbf{71\%}$$

Set the timer at this setting and record the speed of travel. Confirm by calculating revolution time with the measured speed of travel. Modify the timer setting until correct revolution time is achieved.

Injection Rate in Gallons per Minute:

We calculated the total pesticide solution (water + oil + insecticide) needed at 167.75 gals. We also calculated a revolution time of 26.9 hours. To calculate the chemical injection rate delivered by the injection device in gallons per hour we divide the total insecticide needed by the revolution time.

$$\text{Injection rate} = \frac{\text{Total gallons needed}}{\text{Revolution time}}$$

Substituting the numbers into the equation.

$$\text{Injection rate} = \frac{\text{167.75 gals of pesticide solution}}{\text{26.9 hours/revolution}}$$

$$= \mathbf{6.24\ gals/hour}$$

Injection Rate in Ounces per Minute:

For the insecticide example converting gallons per hour (gph) to ounces/minute (oz/min) we multiply the injection rate in gallons per hour (6.24 gals/hr) by the equivalent number of ounces/min ***([128 oz/gallon ÷ 60 minutes per hour]*** or 2.13 oz/min):

oz/min = 6.24 gals/hr x 2.13

= **14.4 oz/min**

Injection Rate in Milliliters per Minute:

For the insecticide example converting gallons per hour (gph) to milliliters/minute (ml/min) we multiply the injection rate in gallons per hour (6.24 gals/hr) by the equivalent number of ml/min ***([3785 ml/gallon ÷ 60 minutes per hour]*** or 63 ml/min):

ml/min = 6.24 gals/hr x 63

= **394 ml/min**

APPENDIX I

Sample Problem 1

Given: $\pi = 3.14$
1 acre = 43,560 square feet
Area of a circle = π x WR x WR
Circumference = 2 x π x r
1 gallon = 4 quarts
1 quart = 2 pints

You are the owner of a parcel of land that is irrigated by a center-pivot with a length of 1,290 feet (pivot point to the last sprinkler). The water throw of the last sprinkler is an additional 25 feet beyond the end of the last tower. There is no end gun. The distance from the pivot point to the last wheel track is 1,265 feet. The speed of the pivot at the last wheel track is 9.0 feet per minute when the percentage timer is set at 100%.

Problem #1: Calculate the number of acres irrigated by a center-pivot.

$$\frac{3.14 \text{ x } (1{,}315 \text{ ft})^2}{43{,}560 \text{ sq ft/acre}} = \frac{3.14 \text{ x } (1{,}315 \text{ x } 1{,}315)}{43{,}560}$$

= **124.6 acres**

Problem #2: Assume an application of 3 pints per acre of an insecticide is recommended. Calculate the number of gallons of insecticide that is required to treat the entire field?

$$\frac{124.6 \text{ acres x } 3 \text{ pts/acre}}{8 \text{ pts/gal}} = \mathbf{46.7 \text{ gallons}}$$

Problem #3: Calculate the revolution time or time of application to apply the insecticide if the percentage timer on the pivot is set at 100%?

$$\frac{2 \text{ x } 3.14 \text{ x } 1{,}265 \text{ ft}}{9.0 \text{ ft/min}} = \frac{882.7 \text{ minutes}}{60 \text{ min/hr}}$$

= **14.7 hours**

Problem #4: Calculate the injection rate in millimeters per minute?

$$\frac{46.7 \text{ gal}}{14.7 \text{ hr}} = 3.18 \text{ gph} \quad \text{or} \quad \text{ml/min} = 3.18 \text{ x } 63$$

= **200 ml/min**

Sample Problem 2

Given:

π = 3.14
1 acre = 43,560 square feet
Area of a circle = π x WR x WR
Circumference = 2 x π x r

1 gallon = 4 quarts
1 quart = 2 pints
450 gpm = 1 acre-inch /hour

You are interested in applying your pre-emergence herbicide through your center-pivot irrigation system. Your cropping system has the pivot split between corn and soybeans and you want to apply the herbicide only to the corn side of the field. The herbicide label indicates the product needs to be applied along with 0.50 inches of water. The flow meter at the well shows a pumping rate of the well at 900 gallons per minute. The wetted radius is 1,000 feet and the distance from the pivot point to the last wheel track is 990 feet. The speed of travel at the last wheel track is 6.5 feet per minute at the percentage setting of 100%.

Problem #1: Calculate the number of *corn acres* irrigated by the center-pivot?

$$\frac{3.14 \times (1{,}000\text{ ft})^2 \times 0.5}{43{,}560\text{ sq ft/acre}} = \frac{3.14 \times (1{,}000 \times 1{,}000)}{43{,}560} \times 0.5$$

= **36 acres** (for 1/2 of the pivot)

Problem #2: Assuming an application of 1.5 pints per acre of the herbicide, calculate the number of gallons of chemical that is required to treat the *corn acres*?

$$\frac{36\text{ acres} \times 1.5\text{ pts}}{8\text{ pts/ gal}} = \frac{54}{8}$$

= **6.75 gallons** (for 1/2 of the pivot)

Problem #3: Calculate the time to complete one half of a revolution. Consider the pivot's average application efficiency at 90%. Hint: Calculate the time to complete one revolution, then times by one half.

$$\frac{0.50\text{ in}}{0.90} = \mathbf{0.56\text{ in}}$$

0.56 in x 72.1 acres = **40.1 acre-in**

$$\frac{900\text{ gpm}}{450} = \mathbf{2\text{ acre-inches/hour}}$$

$$\frac{40.1\text{ acre-inches}}{2\text{ acre-inches/hour}} = 20.0\text{ hrs} \times 0.5\text{ (half revolution)}$$

= **10.0 hrs** (1/2 of a revolution)

Problem #4: Calculate the injection rate (to treat one half of the pivot) in ounces per minute?

$$\frac{6.75\text{ gal} \times 2.13}{10.0\text{ hr/rev}} = \mathbf{1.44\text{ oz/min}}$$

Sample Problem 3

Given:

$\pi = 3.14$
1 acre = 43,560 square feet
Area of a circle = π x WR x WR
Circumference = 2 x π x r
1 gallon = 4 quarts
1 quart = 2 pints

Your best management practices implementation plan recommends putting 30 lbs of nitrogen through the pivot during June. Your application will accompany a normal irrigation of 0.75 inches of water at a pivot timer setting of 21%. At this setting the travel speed at the last wheel track is 2.9 feet per minute. The wetted radius (pivot point to the end of the throw of the last sprinkler) is 1,295 feet with no water application beyond that point. The distance from the pivot point out to the last wheel track is 1,250 feet.

Problem #1: Calculate the number of acres irrigated by the center-pivot?

$$\frac{3.14 \text{ x } (1295 \text{ ft})^2}{43{,}560 \text{ sq ft/acre}} = \frac{3.14 \text{ x } (1{,}295 \text{ x } 1{,}295)}{43{,}560}$$

= **120.9 acres**

Problem #2: Your fertilizer dealer supplies 32% Urea Ammonium Nitrate (UAN). Determine the total amount of 32% fertilizer necessary to apply 30 lbs of Nitrogen to the entire field?

$$\frac{30 \text{ lbs N}}{3.54 \text{ lbs N/gal (32\% UAN)}} = 8.5 \text{ gals/acre of 32\% UAN x 120.9 acres}$$

= **1,028 gallons of 32% UAN**

Problem #3: Calculate the total time of application?

$$\frac{2 \text{ x } 3.14 \text{ x } 1{,}250}{2.9 \text{ ft/min}} = \frac{2{,}707 \text{ min}}{60 \text{ min/hr}}$$

= **45.1 hours**

Problem #4: Calculate the injection rate in gallons per hour?

$$\frac{\text{Total volume}}{\text{Revolution time}} = \frac{1{,}028 \text{ gals}}{45.1 \text{ hrs}}$$

= **22.8 gph**