Using Chemigation Safely and Effectively

Calibration Workbook

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HOW TO USE THIS WORKBOOK

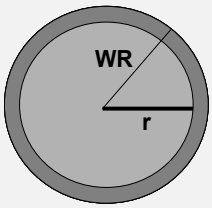
This booklet is designed to be used with the ***Calibration*** section of the Using Chemigation Safely and Effectively training DVD. The workbook examples correspond with the DVD presentation. During the presentation, you are encouraged to ask questions, and work through the calculations in this workbook 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. Calibrating 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: Thosewho use a calculator with a built-in pi (B) 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:

$$CWT = 2 \times \pi \times r$$



where:
CWT = Circumference of the last wheel track (ft)
π = 3.14
r = pivot radius – distance between pivot point and last wheel track (ft)

$$RT_{100} = \frac{CWT}{TS \times 60}$$

where:
RT_{100} = Revolution time at 100% speed (hour)
CWT = Circumference of the last wheel track (ft)
TS = center pivot travel speed (ft/min)

$$WA = \frac{\pi \times WR^2}{43{,}460}$$

where:
WA = Wetted area treated (ac)
WR = Wetted radius – distance between the pivot point and the edge of wetted land (ft)

$$TWP = \frac{ID}{WAE} \times WA$$

where:
TWP = Total water pumped (ac-in)
ID = Irrigation depth (in)
WAE = Water application efficiency (%)
WA = Wetted area of the center pivot (ac)

$$RTR = \frac{TWP}{\left(\frac{PFR}{450}\right)}$$

where:
RTR = Revolution time required (hour)
TWP = Total water pumped (ac-in)
PFR = Pump flow rate (gal/min)

$$PSS = \frac{RT_{100}}{RTR} \times 100$$

where:
PSS = Pivot speed settings (%)
RT_{100} = Revolution time at 100% speed (hour)
RTR = Revolution time required (hour)

$$VA = \frac{VPDA}{VPP}$$

where:
VA = Volume needed of product per acre (gal/ac)
VPDA = Volume of product desired per acre (lb/ac)
VPP = Volume of product per gallon (lb/gal)

$$TVR = WA \times VA$$

where:
TVR = Total volume product required (gal)
WA = Wetted area of the center pivot (ac)
VA = Volume needed of product per acre (gal/ac)

$$TVR_p = WA \times VA$$

where:
TVR_p = Total volume of pesticide required (quartz + crop oils)
WA = Wetted area of the center pivot (ac)
VA = Volume needed of product per acre (quartz + crop oils/ac)

$$TVR_w = TVR_p * \frac{PFW}{PPM}$$

where:
TVR_w = Total volume of water required (quartz)
PFW = Parts of fresh water (-)
PPM = Parter of pesticide mixture (-)

$$IR_{gph} = \frac{TVR}{RTR}$$

$$IR_{oz/m} = IR_{gph} \times 2.13$$

$$IR_{mL/m} = IR_{gph} \times 63$$

where:
IR_{gph} = Injection rate (gal/hour)
TVR = Total volume product required (gal)
RTR = Revolution time required (hour)
$IR_{oz/min}$ = Injection rate (oz/min)
$IR_{mL/min}$ = Injection rate (mL/min)

π	=	3.14
1 ac	=	43,560 ft^2
450 gpm	=	1.0 ac-in/hour
1,440 minutes	=	24 hours
1 gallon	=	128 oz.
3,785 milliliters	=	1 gal
2 pints	=	1 qt.
4 quarts	=	1 gal
1 gallon/hour	=	2.13 oz./min
1 gallon/hour	=	63 mm/min
1 gal of UAN 28%	=	2.98 lb of nitrogen
1 gal of UAN 32%	=	3.54 lb 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 at 100% speed (RT_{100}) – Full Circle:
Revolution time at 100% speed 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 (*CWT*) considering the distance from the pivot point to the last wheel track (pivot radius – *r*) of 1,250 ft. The second part consists in calculating the revolution time at 100% speed (RT_{100}) considering a travel speed of the center pivot (*TS*) of 6.8 ft/min (**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%).**

$$CWT = 2 \times \pi \times r$$

$$CWT = 2 \times 3.14 \times 1{,}250$$

$$CWT = 7{,}850\ ft$$

$$RT_{100} = \frac{CWT}{TS \times 60}$$

$$RT_{100} = \frac{7{,}850}{6.8 \times 60}$$

$$RT_{100} = 19.2\ hours$$

Wetted Area Treated (*WA*) – Full Circle:
The wetted area treated is calculated by the area of a circle. Considering a wetted radius (*WR*) – distance between the pivot point and the edge of wetted land – of 1,300 ft, the wetted area treated (*WA*) can be calculated as:

$$WA = \frac{\pi \times WR^2}{43{,}460}$$

$$WA = \frac{3.14 \times 1{,}300^2}{43{,}560}$$

$$WA = 121.8\ ac$$

Total Water Pumped (*TWP*):
To calculate the total water pumped by the irrigation system (*TWP*), multiply the irrigation depth (*ID*) times the wetted area (*WA*). Keep in mind that it is important to consider the water application efficiency (*WAE*) of the irrigation system, which in this case we will use 85%. Considering an irrigation depth of 0.75 in with a water application efficiency 85%, the actual irrigation amount selected on the pivot panels should be 0.88 in. On other words, 0.88 in of water must be pumped to achieve a net irrigation depth of 0.75 in. Once the irrigation depth is defined, then the total water pumped is calculated as:

$$TWP = \frac{ID}{WAE} \times WA$$

$$TWP = \frac{0.75}{0.85} \times WA$$

$$TWP = 0.88\ (in) \times WA$$

$$TWP = 0.88 \times 121.8$$

$$TWP = 107.2\ ac - in$$

Revolution Time Required (*RTR*):

This is an important process during the calculation process as the revolution time required (*RTR*) will allow the determination of the right pivot speed setting that will attend the nutrient application rate selected in the field. Center pivots have, on average, the capacity to cover 1 ac-in/hour under a pumping flow rate (*PFR*) of 450 gallons per minute (gpm). If the pump flow rate differs from this number, the amount covered (acre-in per hour) will also change. Considering a pump flow rate of 750 gpm, then this pivo can cover 1.7 ac-in/hour. To calculate the revolution time required, divide the total water pumped by the pumping capacity, as shown below:

$$RTR = \frac{TWP}{\left(\frac{PFR}{450}\right)}$$

$$RTR = \frac{TWP}{\left(\frac{750}{450}\right)}$$

$$RTR = \frac{TWP}{1.7\ (ac - in/hour)}$$

$$RTR = \frac{107.2}{1.7}$$

$$RTR = 63.1\ hours$$

Pivot Speed Setting (PSS):

To set the percent timer on the center pivot (or pivot speed setting – *PSS*) to get a revolution time required (*RTR*) of 63.1 hr, we must refer back to the to the revolution time for the pivot at 100% speed (RT_{100}). This information will provide the speed in which you will select at the pivot panel. This speed will attend the 0.88 in of irrigation water application (with net irrigation water application of 0.75 in). To calculate the pivot speed setting, divide the revolution time for the pivot at 100% by the revolution time required to apply 0.88 in of irrigation water, as provided below:

$$PSS = \frac{RT_{100}}{RTR} \times 100$$

$$PSS = \frac{19.2}{63.1} \times 100$$

$$PSS = 30\%$$

Note: 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.

Volume Needed per Acre (*VA*):

Now that the pivot speed settings was defined based on the irrigation water amount selected for this chemigation scenario, it is time to calculate the volume of the product will be injected in this irrigation event. First, we start by calculating the volume of UAN needed per acre (*VA*). Divide the volume of product desired per acre (*VPDA*) by the volume of product per gallon (*VPG*). Suppose we want to apply 30 lb. of nitrogen per acre using 28% Urea-Ammonia Nitrate fertilizer (UAN) and considering that there are 2.98 lb. of nitrogen in a gallon of 28% UAN, VA can be calculated as:

$$VA = \frac{VPDA}{VPG}$$

$$VA = \frac{30}{2.98}$$

$$VA = 10.1\ gal/ac$$

Note: 28% UAN = contains 2.98 lb. of nitrogen in a gallon; 32% UAN = contains 3.54 lb. of nitrogen in a gallon

Total Volume of Product Required (*TVR*):

To calculate the total volume of product (*TVR*) required for a particular field, multiply the volume needed per acre (*VA*) times the wetted area of the field (*WA*). Calculation process is presented below:

$$TVR = WA \times VA$$

$$TVR = 121.8 \times 10.1$$

$$TVR = 1{,}230\ gal$$

Injection Rate (IR):

Because we know that the pivot will take 63.1 hours to cover this field at a 0.88 in of irrigation water application, and we also know that 1,230 gallons of 28% UAN fertilizer will be required to apply 30 lb. of nitrogen per acre, then we can calculate the injection rate (IR_{gpm}) selected at the injection pump. Simply divide the total volume of product required (*TVR*) by the revolution time required (*RTR*). The calculation is presented below:

$$IR_{gph} = \frac{TVR}{RTR}$$

$$IR_{gph} = \frac{1{,}230}{63.1}$$

$$IR_{gph} = 19.5\ gal/hour$$

The injection rate can also be calculated in once per minute ($IR_{oz/min}$) or milliliter per minute ($IR_{mL/min}$) by using the following equations:

$$IR_{oz/min} = IR_{gph} \times 2.13$$

$$IR_{oz/min} = 19.5 \times 2.13$$

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

Note: value **2.13** is the conversion factor from gpm to oz/min (128 oz/gallon ÷ 60 minutes per hour).

$$IR_{mL/min} = IR_{gph} \times 63$$

$$IR_{mL/min} = 19.5 \times 63$$

$$IR_{mL/min} = 1{,}228.5\ mL/min$$

Note: value **63** is the conversion factor from gpm to mL/min (3785 ml/gallon ÷ 60 minutes per hour).

PESTICIDE EXAMPLE

In this section we will provide an example of a pesticide application through a center pivot irrigation system. The main difference between this example and the application of nutrient is that the irrigation rate selected is usually under 0.35 in, meaning that the center pivot will operate faster. Calculations procedures are about the same. First, calculate in each speed the pivot will operate based on the center pivot characteristics and irrigation rate to define the revolution time. Second, define the amount of product applied to calculate the injection rate selected at the injection pump.
The information provided are:

- Irrigation depth (ID) = 0.30 in
- Water application efficiency (WAE) = 85% or 0.85
- Wetted area (WA) = 122 ac
- Pumping flow rate (PFR) = 725 gpm
- Revolution time at 100% speed (RT_{100}) = 19.2 hours
- Volume of product desired per acre (VA) = 2 pints of pesticide/ac + 2 pints of crop oils/ac.
- Dilution = 7 parts of fresh water per 4 parts of product desired.

Total Water Pumped (*TWP*):
Based on an irrigation depth (*ID*) of 0.30 in, a water application efficiency of 85%, and a wetted area (*WA*) of 122 ac, the total water pumped (*TWP*) can be calculated as:

$$TWP = \frac{ID}{WAE} \times WA$$

$$TWP = \frac{0.30}{0.85} \times 122$$

$$TWP = 42.7\ ac - in$$

Revolution Time Required (*RTR*):
Based on a total water pumped (*TWP*) of 42.7 ac-in and a pumping flow rate of 750 gpm, the revolution time required (*RTR*) can be calculated as:

$$RTR = \frac{TWP}{\left(\frac{PFR}{450}\right)}$$

$$RTR = \frac{42.7}{\left(\frac{725}{450}\right)}$$

$$RTR = 26.5\ hours$$

Pivot Speed Setting (PSS):
Based on a revolution time at 100% speed (RT_{100}) and a revolution time required (*RTR*) to apply 0.35 in of water, the pivot speed setting (*PSS*) can be calculated as:

$$PSS = \frac{RT_{100}}{RTR} \times 100$$

$$PSS = \frac{19.2}{26.5} \times 100$$

$$PSS = 72.4\%$$

Note: 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.

Total Volume of Product Required (TVR_p) and Total Volume of Mixture (*TVM*):
For this scenario, we will an insecticide that recommends a volume of product required per acre (*VA*) of 2 pints of pesticide/ac + 2 pints of crop oils/ac. Since there are 2 pints in a quart, the equivalent volume is 2 quarts of the pesticide + oil combination. To calculate the total volume of product (TVR_p) required for a particular field, multiply the volume required per acre times the wetted area of the field (*WA*). Calculation process is presented below:

$$TVR_p = WA \times VA$$

$$TVR_p = 122 \times 2$$

$$TVR_p = 244\ quartz + oils$$

Once the total volume of product required (TVR_p) is defined, there is still a need for converting this number to gallons of solution applied, or total volume of product required (*TVR*). But first, calculate the total volume of water required (TVR_w) considering that the insecticide label calls for the pesticide mixture to be diluted with fresh water in a ratio of 7 parts fresh water (*PFW*) to 4 parts pesticide mixture (*PPM*). The calculation process is presented below:

$$TVR_w = TVR_p * \frac{PFW}{PPM}$$

$$TVR_w = 244 * \frac{7}{4}$$

$$TVR_w = 427\ quarts\ of\ water$$

To calculate the total volume of mixture required (*TVR*) in gallons, use the conversion factor of 4 quartz to each gallon, as calculated below:

$$TVR = \frac{TVR_p + TVR_w}{4}$$

$$TVR = \frac{244 + 427}{4}$$

$$TVR = 167.75\ gal$$

Injection Rate (IR):

Considering a total volume of product required (*TVR*) of 167.75 gal and a revolution time required (*RTR*) of 26.5 hours, the injection rate (IR_{gph}) selected at the injection pump can be calculated as:

$$IR_{gph} = \frac{TVR}{RTR}$$

$$IR_{gph} = \frac{167.75}{26.5}$$

$$IR_{gph} = 6.33\ gal/hour$$

The injection rate can also be calculated in once per minute ($IR_{oz/min}$) or milliliter per minute ($IR_{mL/min}$) by using the following equations:

$$IR_{oz/min} = IR_{gph} \times 2.13$$

$$IR_{oz/min} = 6.33 \times 2.13$$

$$IR_{oz/min} = 13.5\ oz/min$$

Note: value **2.13** is the conversion factor from gpm to oz/min (128 oz/gallon ÷ 60 minutes per hour).

$$IR_{mL/min} = IR_{gph} \times 63$$

$$IR_{mL/min} = 6.33 \times 63$$

$$IR_{mL/min} = 399\ mL/min$$

Note: value **63** is the conversion factor from gpm to mL/min (3785 ml/gallon ÷ 60 minutes per hour).

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 own 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 center pivot track speed of the last wheel track is 9.0 feet per minute when the percentage timer is set at 100%. **Question:** what the injection rate in mL/min is considering you an insecticide application recommendation of 3 pint/ac?

Step 1. Calculate the revolution time at 100% speed (*RT100*). *CWT* is the circumference of the last wheel track.

$$CWT = 2 \times \pi \times r$$

$$CWT = 2 \times 3.14 \times 1{,}265$$

$$CWT = 7{,}944.2\ ft$$

$$RT_{100} = \frac{CWT}{TS \times 60}$$

$$RT_{100} = \frac{7{,}944.2}{9 \times 60}$$

$$RT_{100} = 14.7\ hours$$

Step 2. Calculate the wetter area (*WR*).

$$WA = \frac{\pi \times WR^2}{43{,}460}$$

$$WA = \frac{3.14 \times (1290 + 25)^2}{43{,}560}$$

$$WA = 124.6\ ac$$

Step 3. Total Volume of Product Required (*TVR*).

$$TVR = WA \times VA$$

$$TVR = 124.6 \times \frac{3}{8\ pint/gal}$$

$$TVR = 46.7\ gal$$

Step 4. Calculate the injection rate (*IR*) in mL/min.

$$IR_{gph} = \frac{TVR}{RTR}$$

$$IR_{gph} = \frac{46.7}{14.7}$$

$$IR_{gph} = 3.18\ gal/hour$$

$$IR_{mL/min} = IR_{gph} \times 63$$

$$IR_{mL/min} = 3.18 \times 63$$

$$IR_{mL/min} = 200\ mL/min$$

Sample Problem 2

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 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 timer setting of 100%. **Question:** what the injection rate in oz/min is considering you an herbicide application recommendation of 1.5 pint/ac?

Step 1. Calculate the wetter area (*WR*) for the corn field (half of center pivot).

$$WA = \frac{\pi \times 1{,}000^2}{43{,}460} \times 0.5$$

$$WA = \frac{3.14 \times 1{,}000^2}{43{,}560} \times 0.5$$

$$WA = 36\ ac$$

Step 2. Calculate the total water pumped (*TWP*) considering a water application efficiency of 90% (or 0.90) for the corn field:

$$TWP = \frac{ID}{WAE} \times WA$$

$$TWP = \frac{0.50}{0.90} \times 36$$

$$TWP = 20\ ac - in$$

Step 3. Calculate the revolution time required (*RTR*) for the corn field:

$$RTR = \frac{TWP}{\left(\frac{PFR}{450}\right)}$$

$$RTR = \frac{20}{\left(\frac{900}{450}\right)}$$

$$RTR = 10\ hours$$

Step 4. Calculate the total volume of product required (*TVR*).

$$TVR = 36 \times VA$$

$$TVR = 124.6 \times \frac{1.5}{8\ pint/gal}$$

$$TVR = 6.75\ gal$$

Step 4. Calculate the injection rate (*IR*) in oz/min.

$$IR_{gph} = \frac{TVR}{RTR}$$

$$IR_{gph} = \frac{6.75}{10}$$

$$IR_{gph} = 0.675\ gal/hour$$

$$IR_{mL/min} = IR_{gph} \times 2.13$$

$$IR_{mL/min} = 0.675 \times 2.13$$

$$IR_{mL/min} = 1.44\ oz/min$$