April 1993 (reformatted May 2000)

Chemigation Calibration for Center Pivot Irrigation Systems

A Workbook for Certified Pesticide Applicators

To accompany the VHS tape "Chemigation Calibration"

Based on materials developed by: The University of Nebraska

Developed for South Carolina by:

Rachel C. Rowe & Robert G. Bellinger

Pesticide Information Program, Department of Entomology, Soils and Plant Sciences
R.G. Bellinger, Ph.D., Extension Pesticide Coordinator
Extension Entomology, 114 Long Hall, Clemson, South Carolina 29634-0315
Telephone (864) 656-3111

Chemigation Calibration
for Center Pivot Irrigation Systems
A Workbook for Certified Pesticide Applicators

General Information

Chemigation is the application of agricultural chemicals through an irrigation system by injecting these chemicals into the irrigation water.

Chemigation Calibration is the measurement and adjustment of the chemical injection and the irrigation systems to insure that an accurate amount of chemical is being both injected and applied.

Calibration is NOT a cost of application. Costs ARE often incurred, when you do not calibrate because:

- Applying too little or too much chemical is a waste of money;
- Applying too much chemical is illegal;
- Applying too much chemical may damage crops;
- Applying too much chemical may contaminate ground or surface water;
- Applying too much chemical is a safety hazard,

Full Circle Center Pivot Irrigation Systems

Center pivot sprinkler irrigation systems are normally designed to run with the end gun operating. When the end gun is off, the flow from the other sprinklers will typically increase 2-10%. Consequently, the injection rate during chemigation would have to be changed each time the end gun turned off.

It is best to *leave intermittent end guns OFF when chemigating* t o prevent contamination of non-target sites if the end gun does not turn off, or over-application in spots if it does.

During chemigation, two or three sprinkler heads adjacent to the pivot point should also be turned off to prevent contamination of the pivot point and the equipment located there *and* for applicator safety during calibration and inspection.

Chemical Injection Systems

Injection systems consist of:

- an easily adjustable injection pump,
- a calibration tube,
- a nurse or chemical tank with agitation,
- chemically resistant hoses, clamps and fittings, and
- appropriate shutoff devices and backflow valves.

Separate injection systems should be maintained for fertilizers and for pesticides. Fertilizers are applied in high volumes that require high capacity injection pumps and large (1000+ gal) supply tanks. Pesticides are delivered in much lower volumes, requiring lower capacity injection systems and smaller (50 to 100 gal) supply tanks.

Calibrating Full Circle Center Pivot Systems for Chemigation

With a few minor changes, the following steps can be applied to any type of irrigation/chemigation system, not just a center pivot sprinkler system.

1. Inspect the irrigation system and the chemical injection system for problems or signs of wear.
2. Check the system's uniformity of water application.
3. Measure the following in the field:

- radius to the outer wheel track,
- wetted radius,
- irrigation pump output,
- pivot travel speed.

4. Calculate the following:
   - total acres to be treated,
   - total amount of chemical needed
   - revolution time,
   - chemical injection rate in gal/hr,
   - convert the injection rate units to the units on the calibration tube.

Step 1. Inspection

Before chemigating, you should inspect the irrigation and chemical injection systems for signs of damage or wear. Make sure they are in good working order and operating properly.

Step 2. Uniformity of Water Application

To check the system's uniformity water of application:

1. Set catch containers at 10 ft intervals along the full length of the system. Containers should be straight sided and must be equal in diameter. Set containers in an open area, not under a canopy of growing crops.
2. Operate the system at the pressure to be used when the chemical is applied. System speed should be slow enough to get at least a one half inch application during the check for uniformity.
3. Record the quantity of water in each container and its location.
4. Average the amount of water collected in all containers and compare it to the quantities in the individual containers. If significant deviation (greater or less than 10%) from the average is found at any particular point, nozzles or sprinklers at that location may need replacing.

Step 3. Field Measurements

1. Radius -the distance from the pivot point to the last wheel track. The radius will be used to calculate the number of hours that the pivot takes to complete one circle or the *revolution time.*
2. Wetted radius - the distance between the pivot point and the point where the water throw of the last sprinkler ends and dry soil begins. DO NOT use the end gun. The wetted radius will be used to calculate *acres to be treated.*
3. Irrigation pump output the pumping rate of your well expressed in gallons per minute (gal/min). A working flow meter must be used to accurately measure the well's current output.
4. *Pivot travel speed* is measured at the last wheel track with the system operating. It is expressed in feet per minute (ft/min).

The following equipment will be needed:

Stop watch,
Marking flags,
100 foot measuring tape,
Rainsuit,
Calculator

- Operate the system at a setting and pressure most commonly used for applying either a fertilizer or a pesticide, depending on the type of chemigation you will be doing. Since the system will be operating, you will need a rainsuit to take this measurement.
- Flag the location of either wheel on the outer tower as it begins to move. If the tower moves intermittently, be sure to take the start/stop measurement at the same point in the start/stop cycle of the tower movement.
- As the flag is set, start your stopwatch;
- After 10 minutes, flag the new location of the same wheel;
- Measure the distance between flags or the distance traveled;

Pivot travel speed =

$$\frac{\text{measured distance (ft)}}{\text{10 min}}$$

Soil type, slope, and wheel track depth can all affect travel speed. On rolling terrain, take measurements at several locations, on the level, on an upslope, and on a downslope, and average the three.

Step 4. Calculations

1. **Total acres to be treated or the number of acres irrigated.** For full circle center pivot systems, this is the area of a circle.

Area = πr^2

where: r = the wetted radius, and π = 3.14

The answer will be in square feet. To convert the answer to Acres, you divide by 43,560 sq ft/Acre.

Acres to be treated =

$$\frac{3.14 \times \text{wetted radius}^2}{43{,}560 \text{ sq ft/A}}$$

2. **Total amount of chemical needed.**

Total amount of chemical needed =

Total A to be treated x rate*
*As directed on the product label

If the rate was given in quarts per acre, then you should convert your answer from quarts to gallons:

Number of gals =

$$\frac{\text{No. qts}}{4 \text{ qts/gal}}$$

When applying a nitrogen fertilizer, the rate is given in pounds of N per acre. You must convert from #N/Acre to gal of N solution/Acre in order to determine the Total gals of chemical needed.

3. **Revolution time** of the pivot, or the time it takes the pivot to complete one full circle.

Revolution time is needed to calculate both the injection rate and the amount of water being applied with the chemical. With certain chemicals, some herbicides, for example, a specific amount of water must be applied along with the chemical.

For insecticides, the amount of water applied with the chemical is not important, as long as the right amount of chemical is applied per acre. From an environmental standpoint the chemical should be applied as quickly as possible by moving the pivot rapidly, so the pivot timer should be set at 100%.

The calculations far determining Revolution time when applying insecticides are as follows:

Revolution time (min) =

$$\frac{\text{Circumference (ft)}}{\text{Pivot travel speed (ft/min)}}$$

where:
Circumference = 2 π r
r = the radius or distance from the pivot point to the last wheel track

Pivot travel speed =

$$\frac{\text{measured distance (ft)}}{10 \text{ min}}$$

Because Revolution time is expressed in hours, convert from minutes to hours by:

Revolution time (hr) =

$$\frac{\text{Revolution time (min)}}{60 \text{ min/hr}}$$

For herbicides, the volume of water that accompanies the chemical is a critical part of the treatment. Labels often specify the volume of water in inches that must accompany an application.

With sprinkler irrigation systems, only 85% of the water pumped out by the irrigation system actually reaches the soil surface, because of drift and evaporation. In other words the system is only 85% efficient. When calculating the volume of water to be pumped, you must allow for this.

The calculations needed for determining Revolution time when applying herbicides are as follows:

Amount of water that must be pumped so that the specified amount will reach the soil =

$$\frac{\text{Label requirement (inches)}}{.85}$$

where: .85 = the average efficiency of the pump

Total volume of water that will be required =

Amount of water needed to be pumped x A to be treated

The flow rate of your pump can be read off of the flow meter, then converted from gallons per minute (gpm) to acre-inches per hour (ac-in/hr).

Flow rate (ac-in/hr) =

$$\frac{\text{flow rate (gpm)}}{\text{450 gpm/ac-in/hr}}$$

where: 1 ac-in/hr = 450 gpm

Revolution time (hr) =

$$\frac{\text{Total water required (ac-in)}}{\text{Flow rate (ac-in/hr)}}$$

To determine where you must set the pivot timer to achieve your particular Revolution time, you must first look at a chart developed by the irrigation system's manufacturer. Determine from the chart the time it will take the pivot to make one revolution when set at 100%. Your initial pivot timer setting will be determined by what percent of the 100% time will achieve your Revolution time.

Initial pivot timer setting (expressed as a %) =

$$\frac{\text{Revolution time at 100\% (chart)}}{\text{Your calculated Revolution time}}$$

Set the initial timer setting, and once again, check the travel speed on the ground using your flags, stopwatch, and measuring tape.

Adjust the timer setting until you reach the travel speed that will achieve the calculated revolution time.

Now you are ready to calculate injection rate.

4. **Injection rate**, expressed in gallons per hour. The injection rate will determine the capacity of the pump you will need to do the job. You should always work in the middle ranges of the pump's output. NEVER adjust the pump to less than 10% of its rated capacity nor try to exceed it.

Injection rate (gal/hr) =

$$\frac{\text{Total chemical needed (gal)}}{\text{Revolution time (hr)}}$$

5. **Convert injection rate to match the units on the calibration tube:** Usually, the units on a calibration tube are measured in ounces (oz) or milliliters (ml).

To convert from gal to oz:

gal/hr x 2.13 = oz/min

where: $2.13 = \frac{\text{128 oz/gal}}{\text{60 min/hr}}$

To convert from gal to ml:

gal/hr x 63 = ml/min

where: $63 = \frac{\text{3785 ml/gal}}{\text{60 min/hr}}$

Step 5. Calibration

Remember:

- Make adjustments to the chemical application system ***only while the system is operating***.
- Because various ag chemicals have different densities and viscosities and also differ from plain water, you must **re-*calibrate each time you start a new application.***
- ***Use all appropriate safety precautions and protective clothing when you calibrate.***

Calibrating the injection device:

1. Install the calibration tube in-line on the suction side of the injection device *(not on the non-pressurized discharge side)*;
2. Calculate the initial injection pump setting as a of the maximum pumping rate;

   Initial pump setting =

   $$\frac{\text{Desired injection rate (gal/hr)}}{\text{Max (100\%) pump rate (gal/hr)}}$$

3. Fill the calibration tube with chemical and inject solely from the calibration tube.
4. Turn on the pump and allow it to settle down. Open the valve and, with a stopwatch, measure the chemical flow for one minute.
5. *If* too much chemical is injected, turn the pump down slightly, if too little chemical is injected, turn the pump up slightly. Continue to make rough adjustments to the injection device and try again over several one minute periods, until the calibration tube drains the exact amount of chemical it is supposed to in one minute.
6. Confirm that the chemical is being injected at the correct rate for an extended period (at least two minutes). Check again after an hour or even half a day to be sure there are no calibration errors or equipment malfunctions.

Chemigation Calibration

Directions: Circle the letter of the best answer

1. Chemigation is the application of agricultural chemicals through a(n) ________________ system.
    - **A. irrigation**
    - **B. fertilization**
    - **C. aerial**
    - **D. underground**

2. Calibration of the chemigation system is important because it _____________________.
    - **A. increases efficiency and profitability**
    - **B. controls the amount of chemical being applied to the field**
    - **C. increases personal and environmental safety**
    - **D. All of the above**

3. Applying too little chemical to a field __________________________.
    - **A. is illegal**
    - **B. may damage crops**
    - **C. is a waste of money**
    - **D. All of the above**

4. Applying too much chemical to a field __________________________.
    - **A. is illegal**
    - **B. may damage crops**
    - **C. is a waste of money**
    - **D. All of the above**

5. When the end gun is turned off on a full circle center pivot irrigation system, the other sprinklers will typically _________________________________.
    - **A. increase their flow by 2-10%**
    - **B. increase their flow by 25-50%**
    - **C. decrease their flow by 25-50%**
    - **D. build up pressure and may blow off**

6. Why should 2-3 sprinkler heads near the pivot point of a full circle center pivot irrigation system be turned off when chemigating?
    - **A. So the chemical will be evenly distributed to each sprinkler head**
    - **B. So the pivot point will be identifiable from the air**
    - **C. So the equipment at the pivot point will not become contaminated**
    - **D. So that additional pressure will be created at the end gun**

7. The first thing you should do before calibrating any chemigation system is ____________________.

   A. calculate the total wetted area of the field
   B. run a small tank of chemical mixture through the system at pressure
   C. determine the quantity of chemical needed to treat the field
   D. inspect the irrigation and injection systems for signs of damage or wear

8. Why is it important to check the system's *uniformity of water application?*

   A. To create a wetted area from which to calculate wetted radius.
   B. To discover any equipment problems, such as worn or blocked nozzles.
   C. To insure that the system moves at a steady rate throughout the entire rotation.
   D. To determine when to turn on and off the end gun.

9. When determining *uniformity of water application,* if the amount of water collected in any one catch container is at least 10% greater or less than the average amount collected in all the containers, this indicates ____________________.

   A. that that container has a hole in it
   B. that the system stayed in one place too long
   C. that the water pressure increased momentarily
   D. that that nozzle is worn out or blocked

10. *Total acres to be treated* for a full circle pivot chemigation system is ________________.

   A. 43,560 sq. ft.
   B. the total wetted area or the total area irrigated
   C. the total gallons of water required to treat the whole field
   D. the circumference of the circle made by the outer wheel track

11. The *wetted radius* is __________________________________.

   A. the distance from the pivot point to the outer wheel track
   B. the distance through the pivot point from dry soil on one side to dry soil on the other side
   C. the distance from the pivot point to the point at which you reach dry soil
   D. the distance around the outside wheel track

12. To determine the *amount of chemical required per acre*, you ____________________.

   A. read the label
   B. divide the total number of acres by 43,560
   C. find the area of a circle
   D. consult the table found in your equipment manual

13. When calling the *pivot travel speed,* the system should be _______________________________.

   A. idling or standing still but with the same water pressure as will be used when chemicals are applied
   B. operating at the same speed and water pressure as will be used when chemicals are applied
   C. operating at the same speed but at a 5% higher water pressure because the additional pressure will be needed when chemicals are added to the water
   D. operating slowly and with the end gun on to determine if drift will occur

14. What piece of equipment is *not* needed to measure the system's *pivot travel speed?*

   A. Stop watch
   B. 100 foot measuring tape
   C. Calibration tube
   D. Calculator

15. When measuring the system's *pivot travel speed,* your answer will be in ____________________.

   A. miles per hour
   B. seconds per minute
   C. feet per minute
   D. minutes per foot

16. To determine *revolution time of the pivot* for chemigation, you need to know _____________________________________.

   A. the total wetted area and the pivot travel speed
   B. the circumference of the circle made by the last wheel track and the pivot travel speed,
   C. the quantity of chemical needed to treat the field and the total wetted area
   D. the uniformity of water application and the pivot travel speed

17. The final *injection rate is* usually expressed as __________________________.

   A. gallons per acre
   B. miles per gallon
   C. minutes per gallon
   D. gallons per hour

18. To calibrate the chemical injection device you must _________________________.

   A. wear protective clothing
   B. operate the system
   C. include the chemical that is to be applied
   D. All of the above

19. Where should you locate your calibration tube?

A. On the discharge side of the injection device
B. On the suction side of the injection device
C. In the clamp on top of the pivot's engine box
D. In place of the injection device until the system is calibrated

20. The calibration tube ___________________________.

A. measures the volume of water put out by the system
B. is a graduated cylinder used to mix chemical into the water source
C. monitors the rate at which the chemicals are flowing into the system
D. measures the amount of material being put out by the first nozzle

21. Why should your calibration be made using the actual chemical being applied?

A. You need to make sure the chemical you have chosen will not clog up the equipment.
B. The equipment may slip out of adjustment before you have a chance to apply your chemical
C. The density and viscosity of all agricultural chemicals are different, making your final adjustment dependent on the chemical being used.
D. All of the above

22. During *initial* calibration you need to make adjustments to the system every ____________________.

A. minute
B. 10 minutes
C. half hour
D. hour

23. Why should you check your final calibration over an extended period, such as half a day?

A. To turn on the end gun.
B. To check for calibration error or equipment malfunctions.
C. To see how the plants are responding to the treatment.
D. All of the above

24. To determine the *Total chemical needed* for the field, you ______________________.

A. look for the amount printed on the label
B. measure the output from each nozzle and multiply by 43,560
C. divide the acres to be treated by the chemical required per acre
D. multiply the acres to be treated by the chemical required per acre

25. What do you set the pivot timer on to apply insecticides?

A. 100%
B. 75%
C. 50%
D. 25%

26. What is the difference between calibrating a system for applying a pesticide versus a system for applying a fertilizer?

A. Fertilizers are more corrosive than pesticides.
B. Pesticides are generally applied in lower volumes and require smaller capacity injection pumps and calibration tubes.
C. The system is required to go two full revolutions for fertilizers but not for pesticides.
D. Pesticides require a certain volume of water be applied to the treated area in addition to the chemical.

27. The factors affecting pivot travel speed are: __________________, slope and wheel track depth.

A. temperature
B. time of day
C. soil type
D. size of motor

28. The exact amount of water or the water volume that must be pumped along with the injected chemical is critical when applying _______________________.

A. herbicides
B. insecticides
C. fungicides
D. pesticides

29. The average efficiency of most irrigation systems is ____________________________.

A. 100%
B. 85%
C. 50%
D. 15%

Answer Key: Chemigation Calibration

1. **Answer A is correct.**

2. **Answer D is correct.** Until you calibrate there is no way of knowing whether the amount of chemical being applied is too little, too much or just right. Too much chemical can damage crops, wastes money and is illegal; too little chemical may not do the job, which reduces production and is also a waste of money.

3. **Answer C is correct.**

4. **Answer D is correct.**

5. **Answer A is correct.** Consequently, if you calibrate the system with the end gun on, you will need to re-calibrate if you turn the end gun off because your application rate will change.

6. **Answer C is correct.** Not only to prevent contamination of the equipment but also for the applicator's personal safety.

7. **Answer D is correct.** You should always visually inspect. There is no sense calibrating defective equipment.

8. **Answer B is correct.** Damaged and worn equipment is a common source of calibration error. The chemical application can only be as uniform as the water application. Blocked or worn out nozzles cause irregularities or trouble spots.

9. **Answer D is correct.** If the system is spraying uniformly, it means each nozzle is putting out the same amount of water. Location of any one catch container should not make a difference. If the system stays too long in one place or if there was an increase in water pressure, the volume in a whole line of containers from one end of the boom to the other should be affected, not just one isolated container.

10. **Answer B is correct.** For a full circle pivot irrigation system, this also happens to be the area of a circle.

11. **Answer C is correct.** The sprayed or treated area may reach farther out than the outer wheel, especially if the end gun is turned on. The radius of a circle is always the straight line distance from the center of the circle to its outer edge, in this case, the dry soil. The distance from one side of the circle to the other is the diameter, and the distance around the outside of the circle is the circumference.

12. **Answer A is correct.** The amount of chemical required per acre is the application rate found on the label. The total amount of chemical required will be the total number of acres multiplied by the application rate.

13. **Answer B is correct.** Calculating the system's pivot travel speed is the most critical step in the calibration procedure. Therefore, during calibration, the equipment should simulate as closely as possible an actual application.

14. **Answer C is correct.** The fourth piece of equipment needed is flagging. To determine pivot travel speed you start the stop watch and flag the location of either wheel on the outer tower of the operating irrigation system. Exactly ten minutes later, you flag the outer wheel again, then measure the distance between the two flags with the 100 foot tape. Next you divide, using the calculator, feet by minutes to determine Rate.

15. **Answer C is correct.** Rate is distance over time which you find in both answers A and C. Miles per hour, however, would be used only if greater distances and times were being measured.

16. **Answer B is correct.** The treatment will be completed as soon as the system has made a complete circle around the field. Therefore, if you know the circumference, or distance around the outside of the circle, and the pivot travel speed, or time it takes to move a given distance, together, they will give you the Time it will take for the system to complete one pass around the field.

17. **Answer D is correct.** The final injection rate is expressed as a volume of chemical to be applied over a given period of time. In most cases in the United States, chemical tanks are measured in gallons but liters or milliliters may also be used. D, however, is the only answer expressed as volume over time.

18. **Answer D is correct.** To calibrate the system accurately, you should always calibrate with the chemical being used, because different chemical densities and viscosities will cause the application rate to differ. When working with any agricultural chemicals, you should always wear protective clothing.

19. **Answer B is correct.** You need to know the rate at which the chemical is being injected into the system. You can tell this by the rate it is being sucked into the injection device.

20. **Answer C is correct.** The calibration tube is used strictly for calibration of the system.

21. **Answer C is correct.** Because of C, A is almost correct. But, some of your calculations, such as Total wetted area, Quantity of chemical needed to treat the field, and Rate of travel, are not affected by the density or viscosity of the irrigant being applied.

22. **Answer A is correct.** The initial adjustments are the most critical and should be done frequently and with great care.

23. **Answer B is correct.** Additional monitoring of the system's calibration over longer periods is necessary to catch any problems before they cause trouble.

24. **Answer D is correct.** The formulated chemical per acre can be found in the label directions. If the rate is given in quarts per acre, it can be converted to gallons per acre by dividing by 4 (4 quarts per gallon).

25. **Answer A is correct.** The revolution time for center pivot irrigation systems can be adjusted at the pivot point. The adjustment is made as a percent of full speed. When applying insecticides, the chemical should be applied as quickly as possible, since the

amount of water applied with the chemical is not important. Therefore, the timer is set at 100% of full speed.

26. **Answer B is correct.** If you chemigate, two separate injection systems are required, one for pesticides and one for fertilizers. Fertilizers are applied in much larger volumes per acre. This requires larger volume chemical tanks and higher capacity calibration tubes.

27. **Answer C is correct.** Because these factors vary throughout a field, travel speed must be determined at several locations around the field, and the average travel speed used when calculating revolution time.

28. **Answer A is correct.** The volume or water to be applied with the herbicide is a critical part of the treatment and is recommended in the label directions.

29. **Answer B is correct.** 10% to 20% of irrigation water pumped through a sprinkler irrigation system never reaches the ground because of losses due to drift or evaporation. In order to apply the recommended volume of water with an herbicide, the total volume of water pumped must be increased by 15% to allow for this reduction in the volume of water that actually reaches the ground.

Chemigation Calibration
for Center Pivot Irrigation Systems
Pesticide Applicator Training Evaluation

Circle one response for each item.	SD	Strongly Disagree
	D	Disagree
	N	Neither Agree nor Disagree
	A	Agree
	SA	Strongly Agree
If you have already been active in this behavior, circle	*NA*	*Not Applicable*

As a result of this training…

1.	My knowledge of chemigation calibration has increased.	SD	D	N	A	SA	NA
2.	I better understand the need to calibrate chemigation systems.	SD	D	N	A	SA	NA
3.	I now understand calibration saves money in the long run.	SD	D	N	A	SA	NA
4.	I am more comfortable with the calibration process.	SD	D	N	A	SA	NA
5.	I am more aware of problems to look for when maintaining a chemigation system.	SD	D	N	A	SA	NA
6.	I feel that Clemson Extension is helping me to implement better calibration and maintenance practices on my operation.	SD	D	N	A	SA	

7. I intend to put into practice the following chemigation maintenance and calibration activities: *(Check ALL that apply.)*

9 Regularly inspect the system for signs of damage or wear before each chemical application

9 Check the uniformity of water application of the system before calibrating

9 Re-calibrate each time before starting a new application

9 Wear protective clothing when calibrating a chemigation system

9 Other ____

9 Other ____

(please specify)

Overall, I think this recertification training video was: (circle one)

Poor	Fair	Good	Very Good	Excellent

Overall, I think this recertification training workbook was: (circle one)

Poor	Fair	Good	Very Good	Excellent

What could be done to improve this training?