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CHEMIGATION EQUIPMENT AND CALIBRATION PROCEDURES

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This bulletin is one of two covering chemigation. Companion bulletin B-1024 is titled "Chemigation Practices for Wyoming." Irrigation systems today are being used not only to apply water to crops, but also fertilizers, herbicides, insecticides, fungicides, nematicides, and plant growth regulators (PGR). The process of applying chemicals to crops through irrigation water has been termed chemigation.

The purpose of this bulletin is to provide information needed to chemigate safely and effectively. It is intended to supplement operator's manuals for irrigation and chemical injection systems. This bulletin will focus on equipment and calibration procedures for center pivot sprinkler systems.

CHEMIGATION EQUIPMENT

A correctly engineered chemigation system has the following components:

- irrigation pumping plant
- chemical injection pump
- chemical storage tank with agitator
- calibration devices
- backflow-prevention system
- related safety equipment

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Chemical pollution of ground water or surface water can occur if: 1) water backflows through the chemical injection system and overflows the chemical supply tank; 2) mechanical or electrical failure causes the irrigation pumping plant to shut down, which allows a portion of the water and chemical mixture to flow directly into the irrigation water supply; 3) overapplication occurs due to improperly calibrated equipment; or 4) leaking valves, casings, pipelines, and manifolds are used. The second situation is the most serious. If the chemical injection equipment continues to operate after the irrigation pumping shuts off, the remaining chemical solution could be pumped into the irrigation pipeline. This may allow it to flow directly into the water source or onto the ground and then into groundwater.

The chemigation safety equipment required by the Environmental Protection Agency (EPA) Label Improvement Program (LIP) is the minimum required in every state. States may require more equipment than the EPA lists in its LIP, but never less. Wyoming currently has no requirements concerning chemigation equipment. Since the EPA published its first list of required safety equipment under the LIP, newer and more up-to-date equipment has been developed. The EPA has published updates to the original list of approved safety equipment. Original devices and approved alternatives are given below. Figures 1 and 2 illustrate minimum requirements for anti-pollution devices, and arrangements of chemigation equipment for engine-driven and motor-driven setups, respectively. Contact the EPA, Region 8 Office, to get information on the most up-to-date regulations and approved safety equipment (see Further Information). The following list is current as of January 1995.

List of Alternative EPA-Approved Chemigation Safety Equipment

Original Device

Functional, normally closed, solenoid-operated valve located on the intake side of the injection pump.

Alternative Device 1

Functional spring-loaded check valve with a minimum of 10 pounds per square inch (psi) cracking pressure. The valve must prevent irrigation water under operating pressure from entering the pesticide injection line and must prevent leakage from the pesticide supply tank on system shutdown. This valve must be constructed of pesticide-resistant materials. *[Note: this single device can substitute for both the solenoid-operated valve and the functional, automatic, quick-closing valve in the pesticide injection line.]*

Alternative Device 2

Functional, normally closed, hydraulically operated check valve. The control line must be connected to the main water line so that the valve opens only when the main water line is adequately pressurized. This valve must prevent leakage from the pesticide supply tank on system shutdown. The valve must be constructed of pesticide-resistant materials.

Alternative Device 3

Functional vacuum-relief valve located in the pesticide injection line between the positive displacement pesticide injection pump and the check valve. This alternative is appropriate for only those chemigation systems using a positive displacement pesticide injection pump and is not for use with venturi injection systems. This valve must be elevated at least 12 inches above the highest fluid level in the pesticide supply tank and must be the highest point in the injection line. The valve must open at 6 inches water vacuum or less and must be spring-loaded or otherwise constructed so that it does not leak on closing. It must prevent leakage from the pesticide supply tank on system shutdown. The valve must be constructed of pesticide-resistant materials.

Original Device

Functional main water line check valve and main water line low pressure drain.

Alternative Device 1

Gooseneck pipe loop located in the main water line immediately downstream of the irrigation water pump. The bottom side of the pipe at the loop apex must be at least 24 inches above the highest sprinkler or other type of water-emitting device. The loop must contain either a vacuum relief or combination air and vacuum relief valve at the apex of the pipe loop. The pesticide injection port must be located downstream of the apex of the pipe loop and at least 6 inches below the bottom of the pipe at the loop apex.

Alternative Device 2 - Pumping Over the Hill

The pipe laid in the crest of the hill is downstream of the irrigation water pump. At the crest of the hill, the pipe must contain either a vacuum relief valve or combination air and vacuum relief valve. The bottom of the pipe in the crest of the hill must be at least 24 inches above the highest sprinkler or other type of emitting device, and the chemical injection port shall be located downstream of the crest of the hill and at least 6 inches below the bottom side of the pipe at the crest of the hill.

Alternative Device 3 - Pumping Down the Hill

The field is downstream of the irrigation water source. A vacuum relief valve or combination air and vacuum relief valve is upstream of the injection of the chemical. The inlet pipe must be at least 24 inches above the highest sprinkler or other type of emitting device, and the chemical injection port shall be located downstream of the inlet pipe and at least 6 inches below the bottom side of the inlet pipe.

Alternative Device 4 - Artesian Well

A free-flowing artesian well with a shut-off pressure greater than zero. A pressure gauge is placed at the wellhead.

Alternative Device 5 - Injection at the Pivot Point

The volume of the main line is greater than the volume of the lateral and riser of the pivot. The main line is sloped downhill with the base of the pivot riser at least 24 inches below the bottom of the inlet pipe. Injection is done at the pivot riser. A vacuum relief or combination air and vacuum relief valve is upstream of the injection of the chemical.

Original Device

Positive displacement pesticide injection pump.

Alternative Device 1

Venturi systems, including those inserted directly into the main water line, those installed in a bypass system, and those bypass systems boosted with an auxiliary water pump. Booster or auxiliary water pumps must be connected with the system interlock so that they are automatically shut off when the main line irrigation pump stops, or in cases where there is no main line irrigation pump, when the water pressure decreases to the point where pesticide distribution is adversely affected. Venturi systems must be constructed of pesticide-resistant materials. The line from the pesticide supply tank to the venturi must contain a functional, automatic, quick-closing check valve to prevent the flow of liquid back toward the pesticide supply tank. This valve must be located immediately adjacent to the venturi pesticide inlet. This same supply line must also contain ***either*** a functional, normally closed, solenoid-operated valve connected to the system interlock ***or*** a functional, normally closed, hydraulically operated valve that opens only when the main water line is adequately pressurized. In bypass systems, as an option to placing both valves in the line from the pesticide supply tank, the check valve may be installed in the bypass immediately upstream of the venturi water inlet ***and*** either the normally closed solenoid or hydraulically operated valve may be installed downstream of the venturi water outlet.

Original Device

Vacuum relief valve.

Alternative Device 1

Combination air and vacuum relief valve.

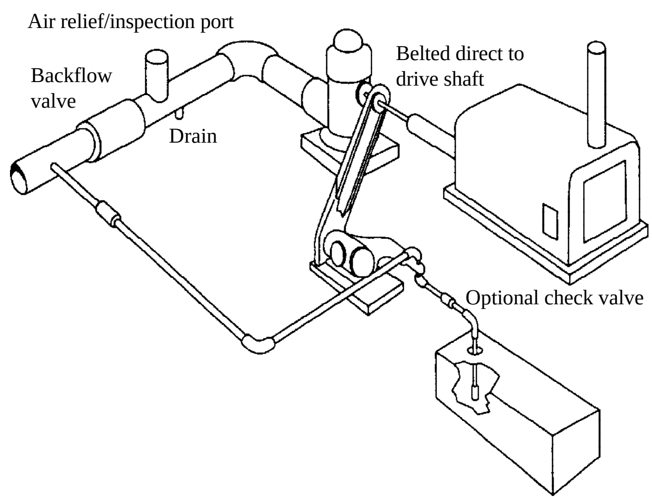

Figure 1. Minimum requirements for antipollution devices and arrangement of equipment for applying chemicals through the irrigation system (engine drive).

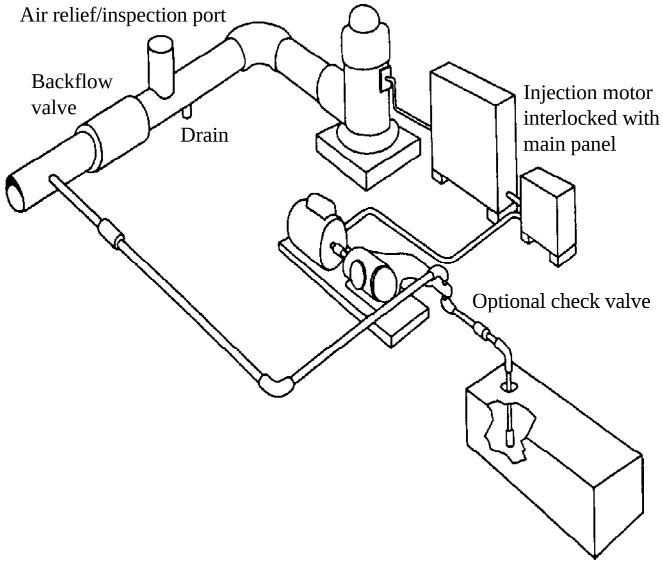

Figure 2. Minimum requirements for antipollution devices and arrangement of equipment for applying chemicals through the irrigation system (motor drive).

Backflow-prevention Devices

The EPA LIP specifies a combination backflow-prevention assembly. This combined assembly consists of an irrigation pipeline check valve, an air/vacuum relief valve, an inspection port, and a low-pressure drain.

The combined assembly is required to:

- prevent water from flowing back into the water source,
- drain minor leakage past the check valve, away from the water source,
- break siphoning action, and
- allow easy inspection for proper operation of the check valve.

The **irrigation pipeline check valve** prevents chemicals from going into the well if the irrigation pump inadvertently stops. The **air/vacuum relief valve** prevents a vacuum from being formed that could draw chemicals through the check valve. The check valve must have positive closing action (spring-loaded) and a watertight seal. It should be easy to repair and maintain. It should not have metal-to-metal seals. Installation fittings should allow for easy removal for maintenance and repair.

The **inspection port** should be located between the mainline check valve and the pump discharge; it should be at least 4 inches in diameter. This will enable visual inspection of the check valve. The check valve should be inspected at least once a year.

Small amounts of chemicals that may leak by the check valve are disposed of through the **low-pressure drain**. The automatic low-pressure drain should be located on the bottom side of the pipeline directly under the inspection port. Some type of cup or dam must be incorporated into the drain valve to intercept minor leakage from the check valve. The flow of the discharge from the drain must be directed a minimum of 20 feet away from the well or water source. This distance may need to be increased, especially in sandy or gravelly soils. It may be possible to incorporate a container to catch the fluid that drains out the low-pressure drain.

If a centrifugal pump is used in the irrigation system and it must be kept primed for automatic operation, a second check valve must be used upstream from the backflow-prevention assembly.

Existing irrigation backflow valves may not be suitable for chemigation, especially if the irrigation system pumps water at high pressure. This means the valve is probably a slow-closing type designed to protect pumps and pipelines from pressure surges. If the irrigation system has an especially large pumping installation, smaller chemigation valves placed near fields being chemigated will be better than a single backflow valve.

Interlocks

The power supply of the injection and irrigation pumps must be interlocked. When properly interlocked, the low-pressure cut-off will stop the injection pump should the irrigation pump's power fail. Example interlocks for internal combustion engines (figure 1) and electric motors (figure 2) are shown.

When using an internal combustion engine, the chemical injection device can be powered by belting to the drive shaft or an accessory pulley of the engine (figure 1). The injection equipment can also be operated off the engine electrical system (12 VDC) or off the power source of the sprinkler system drive. ***However it is connected, it is imperative that if the irrigation water supply stops, the chemical injection also stops.***

Some agricultural chemicals may be flammable. In such cases, explosion-proof electric motors and wiring must be used, a separation distance maintained, or the chemical diluted. Wiring must conform with all requirements specified in the National Electrical Code for hazardous area applications. Check chemical labels for specific requirements.

Chemical Injection Line Check Valve

An anti-backflow chemical injection line check valve prevents water from flowing backward into the chemical tank should the injection pump fail. The 10 psi spring prevents gravity flow of the chemical into the irrigation pipeline when both the injection pump and irrigation pump are shut down. It should be constructed of chemically resistant materials.

Chemical Suction Line Valve

The normally closed solenoid valve, or other alternatives, further ensure that no water will flow into the chemical tank and that no chemical will leave the tank unless it is pumped. This valve provides positive shutoff on the chemical injection line. Power interlocks ensure that all other power will be shut down should any equipment fail, including the center pivot.

Extra Protection

The following safety items are not required, but they afford extra protection when operating a chemigation system:

1. A chemical suction line strainer prevents clogging or fouling of the injection pump, check valve, or other equipment.
2. Installing a valve upstream of the back-flow-prevention assembly provides a clean water source.
3. A clear calibration tube installed on the outlet side of the injection device allows for checking injection rates

Supply Tank

The tank should be constructed of noncorrosive materials such as stainless steel, fiberglass, nylon, or polyethylene. Agitation in the chemical tank is required when wettable powders, dry flowables, flowables, tank mixes, or any other suspended formulations are used. Hydraulic agitation may be sufficient for some soluble chemicals, while mechanical agitation may be necessary for other types of chemicals. Refer to labels for specific instructions. The tanks should be totally self-emptying, such as those with conical bottoms on the tanks.

Hoses, Clamps, and Fittings

Any hoses, gaskets, seals, or other fittings that come in contact with the chemical, from the strainer to the point of injection on the irrigation pipeline, should be made of chemically resistant materials such as polyethylene, polypropylene, EPDM, EVA, Teflon, Hypalon, or Viton. They should also be designed to handle the pressure generated by the chemical injection device. They should also be inspected regularly and replaced at the first sign of wear or deterioration.

Types of Pumps Available

Injection Pumps

The chemical injection pump is the heart of any chemigation system. Within the minimum to maximum pump operating range, a delivery accuracy of plus or minus 1 percent is desirable. The pump should be easily adjusted for different injection rates and mechanically rugged with the internal and external components made of acceptable noncorrosive materials. A variety of injection pumps is available, but the two types normally used on center pivot systems are diaphragm and piston pumps. A venturi unit can be used but is not recommended.

The injection pump capacity should be consistent with application rates of the chemicals that will be applied by chemigation. Chemical application rates can range from 1 pint/acre for some insecticides to more than 30 gallons/acre for liquid fertilizer solutions. Consequently, pump injection rates may need to range from as low as 2 gallons/hour to more than 400 gallons/hour. No single pump can do all jobs. Most pumps are graduated in units or percentages that represent the amount of liquid pumped at a particular setting. However, these settings may be less than exact.

Avoid operating a pump at its maximum output or near its minimum output. Such usage can damage the pump and/or result in inaccurate pumping rates. Piston pumps in particular lose suction capabilities proportionally as stroke length of the piston is reduced for pumping smaller amounts. It is most efficient and consistent to operate within the broad middle capacities of each pump.

Diaphragm pumps

Diaphragm pumps have been used in the chemical industry for many years but have only been actively marketed for chemigation during the last few years. Although most diaphragm pumps are more expensive than piston or venturi units, they have several distinct advantages over other injection units:

- They have a small number of moving components.

- A very limited area of the components is exposed to the chemical being injected. This greatly reduces the potential for corrosion, wear, and leakage compared to piston pumps. Consequently, this greatly reduces potential maintenance costs and the potential for the human and environmental safety risks caused by leaks.

- The design of diaphragm pumps makes it easy to adjust the injection rate while the pump is operating. For most of these pumps, the injection rate is changed by simply turning a micrometer-type adjustment knob.

In general, diaphragm types are the best all-around pumps to use for injecting chemicals through irrigation systems.

Piston pumps

The earliest available and actively marketed injection equipment for agricultural chemicals were piston pumps. Both single and dual piston units are available in a wide range of capacities. Their main advantage is that they can inject at a constant rate against fluctuating pressure in an irrigation system. However, these types of pumps commonly have two important disadvantages for chemigation:

- Piston pumps are subject to accelerated wear of piston seals. Related to this is the potential for increased human and environmental safety risks from resultant leakage and increased maintenance costs.

- Calibration of most piston pumps is relatively time consuming. Altering the injection rate requires that the pump be stopped and the stroke length adjusted mechanically. The pump must then be restarted and the injection rate checked. Several repetitions of this cycle normally are needed to accurately calibrate a piston pump. Some newer piston type pumps can be adjusted while operating.

Piston pumps are most commonly used to apply fertilizers where relatively high injection rates are needed.

Venturi units

Venturi chemical injection units or “pumps” operate by generating a differential pressure or vacuum across a venturi device. This draws the chemical into the irrigation system. ***They are generally not recommended for use on moving irrigation systems.***

The differential pressure is controlled by either:

- a pressure-reducing valve installed in the main line of the irrigation system in parallel with the venturi injection device, or

- a small auxiliary pump (i.e. centrifugal) installed in series with the venturi device with both the auxiliary pump and the venturi device connected in parallel with the irrigation system mainline.

The primary advantage of venturi injection units is their relatively low cost. A major disadvantage of venturi units is the dependence of chemical injection rate upon the available differential pressure. For venturis to be EPA-approved alternatives to positive displacement pumps, some additional fittings are required:

1. The line from the pesticide supply tank to the venturi must contain an automatic, quick-closing check valve to prevent the flow of liquid back toward the pesticide supply tank.

2. This valve must be located next to the venturi pesticide inlet.

3. The main supply line must also contain either a normally closed, solenoid-operated valve connected to the system interlock or an approved alternative device.

4. In bypass systems, an alternative to placing both valves in the line from the pesticide supply tank is to place a check valve in the bypass line immediately upstream of the venturi water inlet and either a normally closed solenoid or hydraulically operated valve immediately downstream of the venturi water outlet.

5. Booster or auxiliary water pumps must be constructed of materials resistant to pesticides.

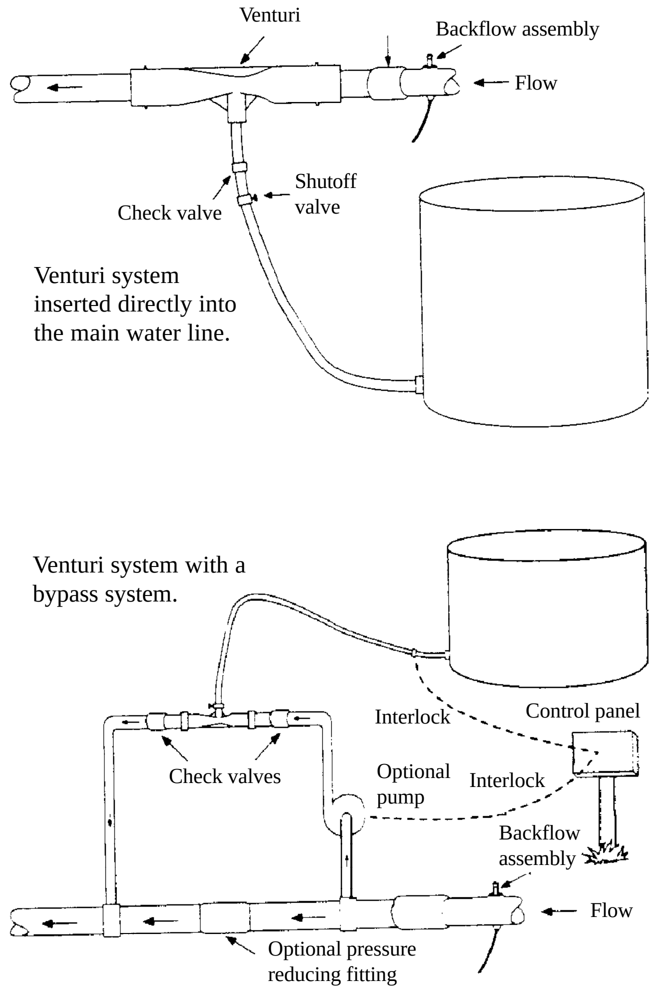

Figure 3. EPA Requirements When You Use a Venturi Unit.

Because the rate of chemical injection is directly dependent upon the differential pressure, any variation in the differential pressure from the calibrated pressure will significantly alter the rate of chemical injection. Variation in flow rate can cause the pressure to vary. Thus, obtaining accurate and consistent rates of chemical injection with a venturi device may be difficult.

CALIBRATION PROCEDURES

Equipment calibration is extremely important in chemigation. Until you calibrate, it is impossible to determine the amount of chemical being applied. Apply too little, and you may not achieve the desired results; apply too much, and you waste money and potentially damage the crop and environment. The objective is to apply the desired amount of chemical (equal to or less than the amount specified on the product label).

Calibrating chemigation equipment is relatively simple, but requires time, equipment, and accurate calculations. ***Always calibrate the irrigation system and injection pump yourself rather than relying on data furnished by the manufacturer.*** The manufacturer's suggestions can eliminate the need for much trial and error, but you still need to determine the exact irrigation water output and injection pump setting. This is because conditions at your work site will not be the same as at the factory.

Measuring Equipment

Measuring equipment includes: a stop watch, a steel measuring tape (preferably at least 100 feet), a pocket calculator, and marking or plot flags large enough to be seen easily at a distance.

Calibration Equipment

Calibration Tube

A calibration tube should be located in the line between the supply tank and the chemical injection pump. It is used to measure output of the injection unit during the calibration process. It should be clear, resistant to breakage, and graduated in units of volume (pints, ounces, milliliters, etc.). Calibration tubes must be large enough to hold enough chemical to be injected over a period of five minutes. (The time it takes to calibrate.)

Although not nearly as accurate as a calibration tube, a pressure relief/regulating valve also can be used for calibration. This valve can be used for "rough" calibrations of pump output by installing it on the end of the injection/metering pump output hose, setting the pressure equal to the irrigation line pressure at the point of injection, and directing the output volume into a measuring can for a specific time period. This method is superior to open discharge pumping into a catch basin because pressure is maintained against the pump.

Calibration involves five basic steps:

1. determine the area in acres to be irrigated
2. determine the amount of material desired per acre
3. determine the total amount of material required (step 1 x step 2)
4. determine the time (in hours) that injection will take place
5. determine the injection rate in gallons per hour (step 3/step 4)

Calibrating the Center Pivot Irrigation/ Chemigation System

The calibration process is based on the given measurements of the irrigation system (length, end gun wetting area, etc.), some common mathematical constants and conversions, and the desired rate of chemical injection. The following calculations must be made: A) area irrigated, B) amount of chemical required, C) travel speed, D) revolution time, and E) chemical application rate. The following example will illustrate the procedure.

A) Area irrigated:

The area irrigated must be calculated with one of several possible formulas. The degree of difficulty in making this calculation depends on the configuration of the field. The simplest case would be a complete circle without intermittent end guns or corner watering systems. The calculation is:

$$\text{Area of the circle in acres} = \frac{\text{pi x r}^2}{\text{43,560 sq. ft. per acre}}$$

where r = the wetted radius (length of pivot plus effective throw of end gun) and pi = 3.1416.

Example:

Assume

$$r = 1300 \text{ ft.: Area} = \frac{3.1416 \times (1300 \times 1300)}{43,560} = 122 \text{ acres}$$

The area irrigated becomes increasingly more complex with partial circles, circles with intermittent end guns, and other configurations. In many situations, it may be wise to leave the end gun turned off because the water pattern is easily distorted by wind. If an end gun shut off fails, it may result in an off-target application.

B) Amount of chemical required:

Chemical required = Acres irrigated x chemical application rate

Example:

Assume 1 qt. chemical is required/acre:

122 acres x 1 qt. chemical/acre = 122 qts. (30.5 gallons)

needed to treat the entire field.

C) Travel speed:

For moving systems, travel speed is one of the most important measurements. When calculating the irrigation system speed, the system should be running "wet" and at the speed and pressure that will be used while chemigating. Always recalibrate when changing speed settings. Avoid determining pivot speed at one percentage setting and mathematically calculating the pivot speeds for other settings, other than to obtain a "rough" figure. Using a stop watch, the proportion of one minute that the end tower is actually moving can be checked against the percentage timer in the pivot control panel.

Two measurements, time and distance, are required to calculate the rotational speed of the pivot. They can be taken in two ways:

1. Record the time necessary for the outer pivot tower to travel a premeasured distance (usually a minimum of 50 feet).

2. Measure the distance traveled by the outer pivot tower in a preselected time (usually a minimum of 10 minutes).

The end result of either method is rotational speed in feet/minute. Be aware that a measurement error of only a few feet or a few minutes can create a significant error in the entire calibration process. If the percentage timer is set at less than 100 percent when determining pivot speed, make sure the start and stop measurements are taken at the same points in the move/stop cycle. (This is not a concern with some oil hydraulic pivots where the end tower moves continuously.) If the terrain is rolling, check rotational speed at several locations in the field and calculate the average value. It may also be wise to verify rotational speed several times throughout the season to account for differences in wheel track resistances due to cover, soil compaction, track depth, etc.

Example:

Assume the measured distance per 10 minutes = 65 ft.:

$$\text{Travel speed} = \frac{65 \text{ ft}}{10 \text{ min}} = 6.5 \text{ ft/min}$$

D) Revolution time:

Circumference of the last wheel track and rotational speed of pivot are the two measurements needed to calculate revolution time. Circumference is calculated by the formula:

Circumference = 2 x pi x r

Where r = the distance in feet from the pivot point to outer wheel track and where pi = 3.1416.

Example:

Assume r = 1300 ft.

Circumference = 2 x 3.1416 x 1300 = 8168 ft.

Even though the owner's manual accompanying the irrigation system might list the system length, the length required for this calculation is from the pivot point to last wheel track (it does not include the overhang). It is a good idea to correctly measure this distance once and permanently record it in the control panel.

Revolution time is calculated by dividing the circumference in feet by rate of travel in feet per minute.

$$\text{Revolution time} = \frac{\text{Circumference (feet)}}{\text{Travel speed (ft/min)}}$$

Revolution time = 8168 ft./6.5 ft/min = 1257 min. per rev.

To convert the revolution time to hours, divide the above answer by 60.

EXAMPLE:

$$\frac{\text{1257min}}{\text{60 min/hr}} = \text{21 hours per revolution}$$

E) Chemical application rate:

The application rate is the amount of formulated material needed to treat the field (Step B) divided by the revolution time in hours (Step D).

Chemical application rate [gallons per hour (gph)] = total material needed (gallons) hrs/revolution

EXAMPLE:

$$\text{Chemical application rate} = \frac{\text{30.5 gal}}{\text{21 hrs}} = \text{1.45 gph}$$

Determining these amounts in gallons per hour (gph) is necessary because most commercially available pumps are rated in gph. Knowing the injection pump capacity in relation to the delivery rate needed can help you establish an initial pump setting. However, be aware that book output values of pumps are normally measured at the factory based on a drive shaft speed of 1,725 revolutions per minute (rpm). Any variance in this shaft speed will alter the pump output. When the injection pump is belt-driven from the engine drive shaft, a tachometer is helpful.

Pump wear will also alter output. Fine tuning should be accomplished using a calibration tube placed on the suction side of the injection pump. Chemicals vary in viscosity and density. Always make the final calibration with the material to be injected and at the operational pressure of the irrigation system. If the volume is small, as with an insecticide, and the calibration tube is measured in milliliters or ounces, gph can be converted to milliliters per minute by multiplying gph by 63.07 or can be converted to ounces per minute by multiplying gph by 2.133.

1. If calibration tube is in milliliters, 1.45 gph x 63.07 = 91.4 ml/minute.

2. If calibration tube is in ounces, 1.45 gph x 2.133 = 3.1 oz/minute.

This amount of chemical, in milliters per minute or ounces per minute, is the working factor to calibrate the injection pump. Using the calibration tube, make coarse adjustments on one-minute time checks. Make a final check over an extended time period (at least five minutes). For an initial injection pump setting, the desired injection rate is divided by the pump capacity to give a percent setting.

EXAMPLE: Required injection rate is 1.45 gph and pump is rated at 4 gph max.

$$\text{Injection rate, \% of capacity} = \frac{\text{1.45 gph}}{\text{4.00 gph}} \times 100 = 36.2\ \%$$

Thus, 36 percent is the suggested first setting for the initial calibration attempt.

For further information:

1. UWCES Bulletin B-1024 *Chemigation Practices for Wyoming*

2. Local Weed & Pest District

3. Local University Extension Office

4. Wyoming Department of Environmental Quality/Water Quality Division

5. Local Conservation District

6. Natural Resources Conservation Service

7. *Wyoming Chemigation Manual for Private and Commercial Pesticide Applicator Certification*, UWCES, Department of Plant, Soil, and Insect Sciences

8. Environmental Protection Agency (EPA) Region 8 Office, Denver, Colorado 1-800-227-8917

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