W 809-F

# Understanding Center Pivot Application Rate

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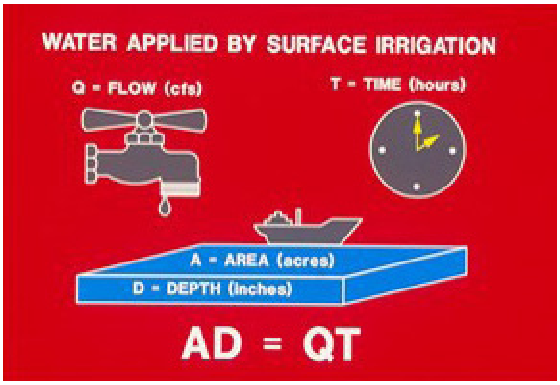
Many irrigation systems are designed with a known flow rate but an unknown application rate (in/hr), such that we don't automatically know how long to operate a system to apply, for example, 1 inch of water. Center pivots rely on a percent timer to adjust the speed of the last tower from 100 percent to 1 percent (percent of time the last wheel motor is operating). With a faster speed, less water is applied, and with a slower speed, more water is applied per revolution. Table 1 shows the application amount per revolution time for a standard design flow of 6 gallons per minute/acre (gpm/ac). Adjusting the percent timer to apply a desired amount of water can be different for every center pivot depending on the design flow, length of the pivot, and the motor chosen to operate the last tower. Older center pivots required a printed chart showing the relationship between percent on-time to application depth that is placed in each individual control panel box. Thankfully, modern control panels perform these calculations internally and automatically set the percent timer to deliver a desired application amount. These panels can also be programed to change the application depth and speed of the center pivot in different pie-shaped zones as it irrigates. Setting a single application depth and operating a center pivot are very easy with modern control panels, whereas programing the pivot to water differently in pie-shaped zones will require greater effort.

*Pivot operating*

An understanding of how center pivot application amount and rate is calculated can be helpful for managing irrigation even though it is calculated by the control panel. One way to better conceptualize the conversion of flow rate to application depth is with the simple equation, AD = QT. This relationship can be visualized as a constant flow (Q in cubic feet per second) from a faucet running into a container that has a constant area (A in acres). If the faucet is turned on for a specified time (T in hours), the result will be a known depth of water (D in inches) in the container. The same is true of irrigation systems that apply water at a known rate into a known area. If the above units of measure are used, there is no need for a conversion constant in the AD = QT equation. However, center pivot flows (Q) are usually in gpm, requiring a conversion constant in the AD = QT equation. Typically, it is easier to calculate application rate (AR) from the AD = QT equation (AR = D/T = Q/A) in inches per hour. Table 2 shows two types of center pivot AR: one based on applying water to the entire circle ($AR_A$, an average rate) and the other directly under the pivot span ($AR_I$, an instantaneous rate).



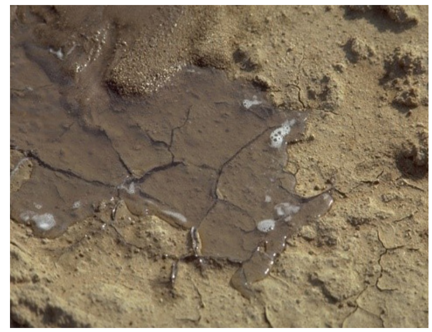

*AD = QT*

As an example of calculating $AR_A$, a 130-acre center pivot with a well and sprinklers designed to deliver 780 gpm applies water at 0.0133 in/hr, which means 0.4 inches would be applied in a 30-hour revolution, as shown in the example in Table 2. You can use the average application rate to make sure the panel is programed correctly by either entering your pivot's design flow rate or a measured flow rate into the $AR_A$ equation along with the acres under the pivot ($Q_C$ and $A_C$ in the $AR_A$ equation). Also, the application amount per revolution can be measured with a rain gauge. Note that only 85 percent to 95 percent of the water applied by the pivot will end up in the rain gauge because sprinklers do not apply water in an entirely vertical direction. Also, multiple rain gauge readings are more representative of application rate due to some disunity of sprinkler application.

*Rain gauge*

$AR_I$ shows how intensely irrigation hits the ground surface. As you move out from the center point, each sprinkler needs to apply more water to cover the increased acreage in each segment added to the circle. Therefore, when using a pivot designed at 6 gpm/ac and spray sprinklers with a 25-foot diameter of throw, the instantaneous $AR_I$ is 1.7 in/hr at 500 feet from the pivot point and 4.2 in/hr at 1,250 feet, as shown in the table below. Even though the $AR_I$ increases along the pivot, the same total amount of water is applied to the entire area; the outer sprinklers move much faster so they need to apply water faster. The $AR_I$ can be reduced by sprinklers that have a greater radius of throw, but these sprinklers require more pressure and produce larger droplets that can impact the soil surface, reducing infiltration. In a Tennessee test on a 4 percent slope, no significant difference in runoff was noted between spray sprinklers and drop spinners with a larger radius of throw. Still, it seems logical to consider using drop-rotating sprinklers to reduce the potential for runoff on sloping ground with silt loam soil that occurs in Tennessee as compared to spray sprinklers that concentrate water in a smaller area.

Most center pivots are designed to be capable of applying 0.3 inches over 24 hours at 6 gpm/ac, meaning you could potentially apply just over 2 inches in a week. Two inches per week or 9 inches in a month is more than enough water to meet a crop's water use requirements in the humid East. Often, the problem with center pivot irrigation is not the supply rate, but the ability to infiltrate water into the soil due to the high $AR_I$, as noted above. The portion of irrigation that runs off is not available for use by the crop. Also, runoff into wheel tracks can increase rutting to the point where a center pivot cannot move across the field as often as desired.


*Pivot run off*

Due to these center pivot application characteristics, there are some base recommendations on how much water to apply per revolution. In flat river bottom grounds, where runoff is not a big concern, application amounts of 0.5 to 0.8 inches per revolution can be utilized. However, on sloping fields or fields where infiltration is an issue, 0.3 to 0.5 inches per revolution leads to a more effective irrigation application. If your goal is to apply 1 inch of water in a week, you could accomplish this by one heavy irrigation, two 0.5-inch irrigations, or three 0.33-inch irrigations. All options result in the same amount of water over the same amount of time if the pivot is running continuously, but the multiple smaller irrigations may have greater evaporation


*Drop spray sprinkler*


*Drop rotating sprinkler*

loss due to wetting the canopy and ground surface more often, whereas the single large irrigation may have significant runoff. Therefore, we recommend setting pivot application amounts as high as possible per revolution without creating significant runoff.

In summary, an understanding of average application rate can help you verify that your center pivot is performing as expected, while instantaneous application rate provides insight into how to avoid excess runoff.

**Table 1: Center Pivot Application Amount by Revolution Time**

| | | |
|---|---|---|
| Design Flow Rate: | 6.0 | gpm/ac |
| Average Application Rate: | 0.0133 | in/hr |

| Time per Revolution (hrs/rev) | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| Application Amount (inches) | 0.13 | 0.27 | 0.40 | 0.53 | 0.66 | 0.80 | 0.93 | 1.06 | 1.19 | 1.33 |

**Table 2: Calculating Application Rates for Center Pivot Irrigation**

| Average AR for water applied to the entire field | Instantaneous AR for water being applied under the span |
|---|---|
| $AR_A = (96.3 \times Q_C) / (A_C \times 43{,}560)$ where,<br>$AR_A$ = average application rate in inches/hour,<br>$Q_C$ = flow for entire system or per acre in gpm<br>$A_C$ = area for entire system in acres or one acre | $AR_I = (D_{PP} \times Q_{AC}) / (72 \times S_D)$ where,<br>$AR_I$ = instantaneous application rate in inches/hour,<br>$D_{PP}$ = distance from the pivot point in feet<br>$Q_{AC}$ = design flow rate in gpm per acre<br>$S_D$ = Sprinkler diameter of throw in feet |
| Example $AR_A$ Calculation<br>$Q_C$ = 780 gpm<br>$A_C$ = 130 acres<br>$AR_A = (96.3 \times 780) / (130 \times 43{,}560) = 0.0133$ in/hr<br>Depth = 0.0133 in/hr x 30 hrs per rev = 0.40 inches | Example $AR_I$ Calculation<br>$D_{PP}$ = 500 feet and 1250 feet<br>$Q_{AC}$= (780/130) = 6 gpm/acre<br>$S_D$ = 25 feet for a spray sprinkler<br>$AR_{I500}$ = (500’ x 6 gpm/ac) / (72 x 25’) = 1.7 in/hr<br>$AR_{I1250}$ = (1250’ x 6 gpm/ac) / (72 x 25’) = 4.2 in/hr |



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