

## Flow Control Devices for Center Pivot Irrigation Systems

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Factors contributing to the need for sprinkler flow rate regulators are discussed.

Sprinkler systems operated on undulating terrain can experience large differences in the pressure supplied to the sprinkler. Since the flow rate of each sprinkler is determined by the pressure in the pipeline, water applied by these systems can be non-uniform.

Pressure regulating devices are used to equalize the pressure supplied to individual sprinklers since uniform water application may save water and increase overall crop production. When installing a sprinkler package on a new system or replacing sprinklers on an existing system, it is important to evaluate the impact of field elevation changes on sprinkler flow rate.

### Do I Need Regulators?

Control of sprinkler flow rate is desirable under the following conditions:

1. Elevation differences exist between sprinklers.
2. Pipeline friction loss causes large differences in pipeline pressure.
3. Excessive pressure is supplied to small sprinklers located on the first few spans of the center pivot.
4. A constant pressure is required for installations where more than one set of sprinklers is supplied by the same pump.

In general, regulators should be installed when the variation in sprinkler flow rate exceeds 10 percent. Variation in sprinkler flow rate can be caused by field elevation changes, pipeline friction loss or on and off cycle of an end gun.

Table I presents elevation changes that will result in a 10 percent change in sprinkler flow rate for a range of sprinkler operating pressures. If the field elevation difference is greater than the values in Table I, regulators should be considered.

For example, a system with an operating pressure of 15 psi and an elevation change of 10 feet would experience greater than 10 percent variation in sprinkler flow rate, and regulating

devices should be installed on all sprinklers. Note that if the operating pressure is greater, a greater elevation difference is required to cause a 10 percent variation in flow rate. Remember that regulating devices do not function until the mainline pressure exceeds the rated operating pressure of the regulator. Typically, the pipeline pressure must be at least 5 psi greater than the pressure rating of the regulator. Thus, operating costs are greater for a system equipped with a regulator.

**Table I. Operating pressures and corresponding elevation differences which will cause a 10 percent variation in sprinkler flow rate.**

|                             |    |    |    |    |    |    |    |    |
|-----------------------------|----|----|----|----|----|----|----|----|
| Operating Pressure (Psi)    | 15 | 25 | 35 | 45 | 55 | 65 | 75 | 85 |
| Elevation Difference (Feet) | 7  | 11 | 15 | 20 | 24 | 29 | 33 | 37 |

The final point to consider is “How much area must be involved?” An elevation difference on the outside of the irrigation system involves a greater amount of water and a greater irrigated area than a similar length of the system located near the pivot point. Small changes in sprinkler output on the outside portion of the system lead to large pressure differences on the remainder of the system. Particular attention should be paid to the outside portion of the irrigated area.

Several factors may affect the point at which it becomes economically justified to add a flow meter. The actual land area needed is based upon the severity of the flow rate variation, the crop under irrigation, the amount of irrigation water applied annually and the price to be received for producing a greater or higher quality yield. A relatively small area of a high value vegetable crop will justify regulators, while the same area planted to corn might not. For example, if one assumes a 10 bu/ac increase in corn yield per inch of water applied, a pressure regulator cost of \$11 each, and a 10 percent variation in flow rate that results in 1-1.5 inches less water application, it would require 10-15 acres to generate enough income to pay for the regulators in a 7-year period at 7 percent interest.

## Impact of Field Elevation Changes

Sprinkler package design is based on no elevation change (level field) between the pivot point and the end tower. If the field is not level, the flow of water out of each sprinkler will be less than design where the pipeline elevation is higher or greater than design where the pipeline elevation is lower than the pivot point.

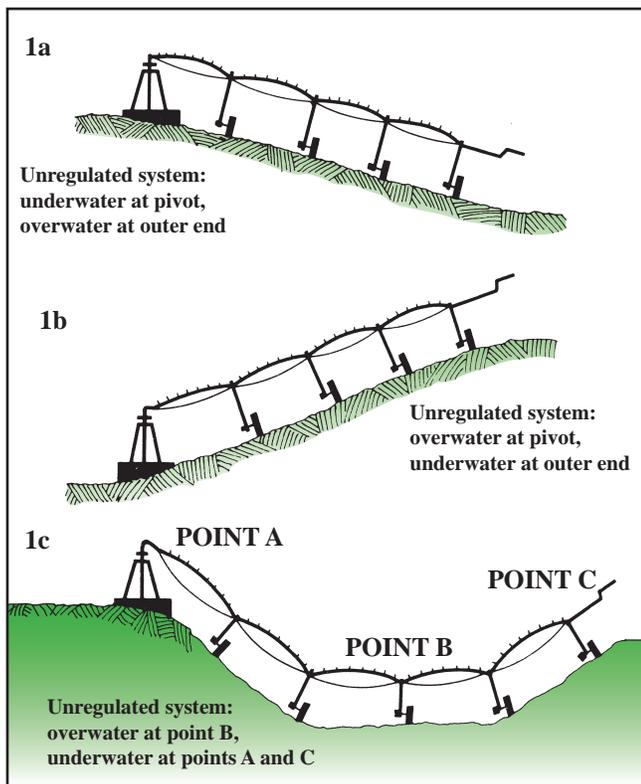


Figure 1. Water application characteristics for unregulated center pivots which result from operating on various terrains.

Due to the pressure differentials caused by elevation differences, if the pivot operates downhill (*Figure 1a*), more water will be applied near the end gun than near the pivot point. Conversely, if the system operates uphill (*Figure 1b*), more water will be applied near the pivot point than near the end gun.

If a system operates over rolling terrain (*Figure 1c*), more water will be applied to the low-lying areas (*Point B*) than to the top of hills (*Points A and C*).

Before installing a sprinkler package, ask “Is the variation in field elevation going to affect water application uniformity?” The answer to this question is becoming more critical as the competition for water supplies becomes more intense.

Documentation of just how much elevation change exists in a field and how much area is involved is commonly overlooked. One way to accurately determine where changes in elevation exist is to conduct a topographic survey of the field to be irrigated. Place flags on a 500-by-500 foot grid across the area to be irrigated. Each flag will represent approximately six acres. Record field elevations at each flag and determine the difference in elevation between the flag and the pivot point by subtracting the elevation at each flag from the pivot

point elevation. Negative values reflect uphill slopes, positive values reflect downhill slopes.

The flags can be grouped together in increments of 20 percent of the greatest elevation difference. For example, if there were 20 flags in the area to be irrigated and the greatest elevation difference was 25 feet, the elevations should be grouped into blocks of five feet of elevation difference. The total number of acres in each block can be calculated by multiplying the number of flags in each five-foot increment by six acres per flag.

Due to the relatively low cost of regulators, if more than 15 percent of the total area has field elevations that cause the sprinkler flow rate to vary more than 10 percent according to *Table 1*, pressure regulators should be installed.

## How Do Regulators Work?

Flow rate out of a sprinkler or spray head is controlled by the size of the sprinkler nozzle and the pressure supplied to the sprinkler. Fluctuations in the pressure supplied to the sprinkler cause the flow rate of the sprinkler to change. The purpose of a pressure regulating device is to maintain a desired sprinkler output despite changes in supply line pressure.

Sprinkler output can be controlled by regulating the flow rate out of the sprinkler using flow control nozzles, or by regulating the pressure supplied to the sprinkler using pressure regulators.

## Flow Control Nozzles

A flow control nozzle consists of a flexible disc which acts as an orifice through which water is emitted. If the operating pressure is below the pressure rating of the flow control nozzle, the disc will remain flat and the flow rate will not be regulated (*Figure 2a*). Further decreases in operating pressure will cause the flow rate to decrease in direct relation to the operating pressure.

When the operating pressure is above the pressure rating of the flow control nozzle, the disc flexes outward. This reduces the size of the nozzle opening, lowering the flow rate of the sprinkler (*Figure 2b*). As the pipeline pressure continues to increase, the disc continues to deflect, further restricting flow. Although the flow rate does increase slightly in the regulated range, the flow rate does remain nearly constant.

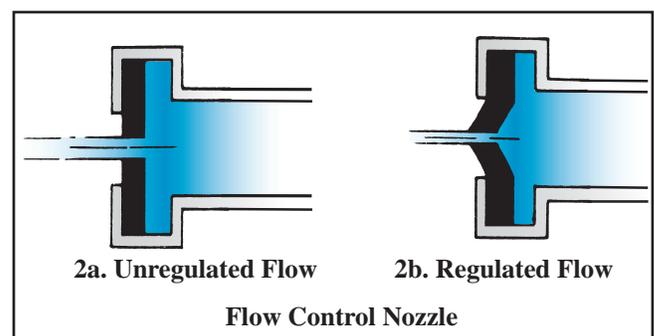


Figure 2. Unregulated and regulated configuration of the flexible disk in a flow control nozzle used to ensure nearly constant flow rate out of a sprinkler.

The minimum pressure required to activate flow control nozzles limits the use of flow control nozzles. Most flow control nozzles do not begin to control flow until the operating pressure is greater than 35 psi. This limits the use of flow control nozzles on many systems equipped with low pressure sprinklers.

Flow control nozzles cannot be selected for specific field situations. Instead, flow control nozzles are selected to operate within a range in operating pressures of 35 to 80 psi. This limits the capability of the nozzle to accurately regulate the water flow rate.

### Pressure Regulators

Pressure regulators control the flow rate of a sprinkler by maintaining a preset pressure to the sprinkler. Pressure regulators (*Figure 3*) respond to pressure between the outlet of the regulator and the base of the sprinkler head.

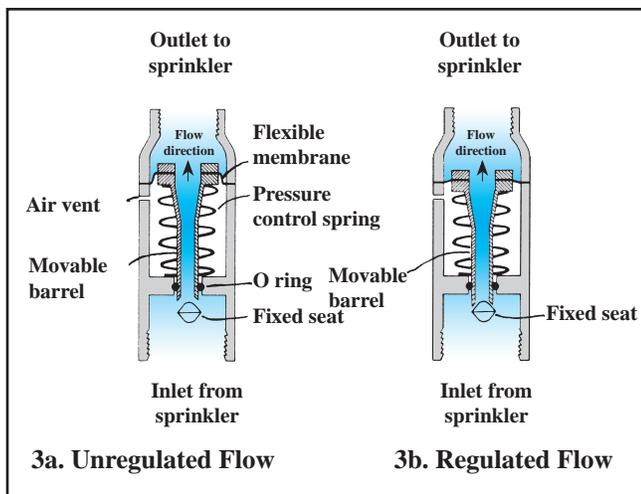


Figure 3. Unregulated and regulated positions of the moveable barrel in a pressure regulator used to ensure constant pressure supply to a sprinkler.

Below design operating pressure, the movable barrel of the regulator is positioned so that the distance between the barrel and the fixed seat is the greatest due to the force exerted upward by the spring (*Figure 3a*). In this situation, sprinkler flow rate is unregulated.

As the pipeline pressure increases, pressure develops between the sprinkler head and the movable barrel of the regulator. This pressure forces the barrel toward the fixed seat, reducing the flow of water to the sprinkler (*Figure 3b*).

Further increases in operating pressure cause the distance between the movable barrel and the fixed seat to narrow even

more. Restricting the flow rate to the sprinkler stabilizes the pressure supplied to the sprinkler. As a result, pressure regulators produce a more constant flow rate than flow control nozzles.

A pressure regulator is selected based upon the design operating pressure of the sprinkler package. Once the sprinkler package is selected, a pressure regulator is chosen to supply the needed flow rate at the design pressure. Typical regulator pressure ratings begin at 10 psi and are available at approximately 5 psi increments up to 50 psi.

The operating pressure of the system should not exceed the pressure rating of the regulator by more than 50 psi. For example, the maximum recommended inlet pressure for a 15 psi regulator is 65 psi. Operating pressures greater than 50 psi above the rated pressure may cause the regulator to fail or lead to extremely erratic performance.

### Summary

Deciding if an irrigation system requires regulators can be difficult. The main reason for installing some form of regulator is to insure that water application is uniform. Installation of regulators commonly is recommended when the sprinkler flow rate varies more than 10 percent from the design specifications. Sprinkler flow rate can be regulated using flow control nozzles or pressure regulators.

Field elevation differences are used to determine the variation in flow rate. A topographic survey will identify areas with elevations different than the pivot point. In most cases, if more than 15 percent of the irrigated area is affected by elevation differences resulting in at least 10 percent variation in the sprinkler flow rate, regulators should be installed.

However, the crop to be irrigated is a very important factor that could cause regulators to be justified with less than 15 percent of the area involved.

### Acknowledgment

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