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Center Pivot Irrigation Systems

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Center pivot irrigation systems, which move in a circular path around a pivot point, can be effective tools to improve irrigation water management and application. The self-propelled machine has removed much of the labor associated with sprinkler irrigation. However, a center pivot system has a high initial cost and major benefits in the form of reduced labor, improved water distribution and management convenience must be realized to justify the cost. Many improvements have been made in center pivot systems in recent years. Major improvements have been made in drive mechanisms, control devices and structure of the machines. The early machines were moved by water motors operated from mainline pressures of 90 to 100 pounds per square inch (psi) and sprinkled water high into the air with large evaporation losses. Today, electric or hydraulic motors at each tower drive the machine. Pressure as low as 12 to 15 psi is adequate for an accurately designed Low Energy Precision Application (LEPA) center pivot driven by electric motors. Water can be placed at low pressure only 8 to 15 inches above the soil surface between circular crop rows with only one to three percent application loss.

Options to consider before buying a center pivot system include: mainline size, length and outlet spacing; type of sprinklers, sprayers or nozzles; and, type of drive mechanism. The choices made may affect the investment cost per acre, operating costs and flexibility for future changes. Larger systems usually cost less per acre than smaller systems. Large mainline sizes cost more than small ones, but have lower operating costs. An outlet spacing of 60 or 80 inches (a multiple of row spacing) along the mainline is needed if LEPA nozzles will be used.

Plan new center pivots to operate at minimum pressure to minimize pumping cost. Each additional 10 psi pivot pressure requires approximately 10 horsepower for each 1,000 gallons per minute pumped into the machine. Horsepower is proportional to system flow rates of more or less than 1,000 GPM. For example, seven horsepower is needed for each 10 psi pivot pressure when the system flow rate is 700 GPM.

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Table 1. Approximate friction loss (PSI) in center pivot sprinklers.

	Mainline pipe diameter, inches			
	6	6-5/8	8	10
Flow rate, GPM	Mainline pressure loss, psi			
A. Quarter-mile system:				
600	11	7		
700	14	9		
800	18	11	4	
900	23	14	5	
1,000	28	17	7	
1,100	33	20	8	
1,200	39	24	9	
B. Half-mile system:				
2,200		146	57	21
2,500			72	27
3,000				38
3,500				60

The use of 8- or 10-inch mainlines allows the system to operate at lower pressure and saves thousands of dollars in reduced pumping cost during the usable life of the system. Table 1 shows approximate pressure loss differences for available mainline sizes. System pressure at the pivot point must be adequate to overcome friction pressure loss and provide the desired pressure at the sprinkler, sprayer or LEPA nozzle. As little as 9 psi is adequate at the pressure regulator just above a LEPA nozzle. For a quarter-mile system carrying 800 GPM, increase the system pressure at the pivot 18 psi for a 6-inch mainline or 4 psi for an 8-inch mainline to overcome friction pressure loss. The added friction loss in the smaller mainline adds 14 psi to the system pressure requirement.

Each additional 10 psi pivot pressure increases fuel costs about $0.50 per hour or $0.22 per acre-inch for each 1,000 GPM when natural gas costs $4.00 per MCF. With $0.08 per KWH electricity, the cost is $0.65 per hour and $0.30 per acre-inch for each additional 10 psi pressure.

Water Application Efficiency

Manufacturers of center pivot water application components are improving equipment and refining system design and nozzle selection techniques to reduce water losses. However, accurate measurement of available flow rate (gallons per minute) is essential for correct system design. Nozzles must be sized precisely to apply the water uniformly. Performance is best when the system is operated as designed, especially at the correct water pressure. Improved technology produces little or no benefit if the design input information is inaccurate or the system is not operated properly.

Field tests on the High Plains indicate that center pivots improve water application efficiency enough to irrigate 20 to 25 percent more acreage than can be covered with furrow irrigation with the same water. Irrigation time of 16 to 17 hours per acre per year with furrow irrigation was reduced to 12 to 13 hours per acre per year with center pivot units. Crop yields were similar. Also, center pivots equipped with LEPA are expected to make 20 to 25 percent more water (100 to 150 GPM in a typical quarter mile center pivot) available to the crop than pivots equipped with impact sprinklers or with spray nozzles on drops. This comparison is shown in Table 2.

Table 2. Pumping rate needed to irrigate with center pivots equipped with conventional impact or spray nozzles versus LEPA nozzles, gallons per minute.

Application rate, inch/day	Conventional (80% efficiency) Mainline length, miles: Quarter	Half	LEPA(98% efficiency) Mainline length, miles: Quarter	Half
0.25	740	3,000	600	2,450
0.30	880	3,620	725	2,960
0.35	1,040	4,230	840	3,420
0.40	1,175	4,800	965	3,930
0.45	1,325	5,400	1,080	4,440
0.50	1,475	6,000	1,200	4,900

Runoff Losses

A major problem when using center pivots is water runoff. Water intake rates of some clay loam, silty clay loam and clay soils are less than the irrigation application rate. Runoff is normally less on sandy and sandy loam soils. Developments in center pivot water applicators that permit lower mainline pressure, while reducing the evaporation rate, also tend to concentrate water on a smaller area and thus increase the water application rate (inches per hour) on the area covered. The wetted pattern is smaller using spray nozzles than with impact sprinklers. LEPA applicators apply water over a smaller soil surface area than spray nozzles.

Reductions in runoff have been achieved by furrow diking and farming in a circular pattern, both integral parts of the LEPA concept. (To farm in a circular pattern, run the machine around the circle without water and use the wheel tracks as row guides.) Other methods of reducing runoff include deep chiseling of clay subsoils, adding organic matter to the soil and using tillage practices that leave the soil open. All of these methods are being used in conjunction with variations in the travel speed of the center pivot, which is the basic means of controlling the amount of water (inches) applied at each irrigation. Runoff is less likely when small amounts of water are applied, but the amount applied must be adequate to meet crop needs and wet the desired soil depth.

Water application amounts for a typical quarter-mile center pivot that irrigates 120 acres are shown in Table 3. One to 1.5 inches, normally an optimum irrigation amount, usually provides sufficient water for the crop until the machine can complete a circle, minimizes runoff and avoids early season depletion of subsoil moisture ideally reserved for high crop water use periods. Application losses are normally less and crop response is better from a single 1.5 inch irrigation than from two 0.75 inch irrigations. However, smaller and more frequent irrigations may be appropriate in some cases with LEPA irrigation. Use formulas following Table 3 to calculate water application for a center pivot system of any length.

TABLE 3. Inches water applied by 1,290-foot center pivot.*

Pivot GPM	Hours to complete 120-acre circle: 12	24	48	72	96	120
400	.09	.18	.36	.53	.71	.89
500	.11	.22	.44	.67	.89	1.11
600	.13	.27	.53	.80	1.06	1.33
700	.16	.31	.62	.93	1.24	1.55
800	.18	.36	.71	1.07	1.42	1.78
900	.20	.40	.80	1.20	1.60	2.00
1,000	.22	.44	.89	1.33	1.78	2.22
1,100	.24	.49	.98	1.47	1.95	2.44
End tower ft/hr	667	334	167	111	83	67
Ac/hr	10	5.0	2.5	1.7	1.3	1.0

* 1,275 feet from pivot to end tower + 15-foot end section.

Calculations for other length pivots can be made using the formulas below.

1. Inches = $\frac{\text{Pivot GPM x hours to complete circle}}{\text{450 x acres in circle}}$

2. Acres per hour = $\frac{\text{Acres in circle}}{\text{Hours to complete circle}}$

3. End tower speed in feet per hour = $\frac{\text{Distance from pivot to end tower in feet x 2 x 3.14}}{\text{Hours to make circle}}$

4. Feet end of machine must move per acre = $\frac{87{,}120}{\text{Distance from pivot to outside wetting pattern}}$

LEPA Irrigation

Low Energy Precision Application (LEPA) irrigation with center pivots is one of the most efficient irrigation methods available today. LEPA irrigation offers both high water application efficiency and low operating pressure. The combined benefits often warrant the purchase cost of LEPA equipment to convert existing center pivots. The extra cost of LEPA on a new center pivot is even more easily justified and should be considered carefully by prospective buyers. Increased crop yield is a third potential benefit, especially where irrigation water is limited.

The precisely planned irrigation system uses special LEPA applicators which release water 8 to 15 inches above the ground. This low release point greatly reduces water evaporation losses. Water application losses from LEPA are only two to three percent compared to 20 to 25 percent from typical impact sprinklers and low pressure spray nozzles. The lower application loss means about 20 percent more water is available for crop use.

System operating pressure can be lower since LEPA heads are located close to the ground and are designed for low pressure. Fuel consumption and cost will average 15 to 20 percent less than that of typical center pivots equipped with low pressure nozzles but about 10 percent more per acre inch of water pumped than furrow irrigation. Actual percentage fuel saving depends upon the reduction in total amount of water pumped and in total pumping head, including pumping lift.

To convert existing center pivots to LEPA, attach new clamp-on drops to the center pivot mainline to apply water between alternate crop rows planted in a circle. To do this, install extra plumbing from existing water outlets on the mainline (usually spaced 8½ to 10 feet apart) to the clamp-on drops attached 60 or 80 inches apart, depending upon crop row spacing. Some vegetable crops require irrigation in every furrow and the drop spacing must match row spacing. Connect special LEPA heads to the drops with a flexible hose long enough to release water 8 to 15 inches above the ground. Remove drops for conventional spray nozzles or impact sprinklers.

Conversion to LEPA can also be accomplished by welding threaded 3/4-inch female pipe couplings to the existing mainline. Since welding destroys the galvanized coating, welded couplings are most applicable for ungalvanized mainlines. Existing goose-necks and drops can be used with the welded couplings.

Center pivots can be purchased from most manufacturers with outlets spaced 60 or 80 inches apart on the mainline. Regular goose-necks and drops can then be used. The LEPA head is connected to the drop with flexible hose so that it is located at the desired height. A pivot span length that accommodates an even number of rows is desirable.

A minimum pressure of 4 psi at the end of the mainline, when it is located at the high point, is adequate when the pressure regulator is installed just above the LEPA head. A pressure regulator is normally installed with each LEPA head but may not be necessary for very level fields. The design objective is 9 psi at the inlet of a six psi regulator. A ground level pivot pressure of 15 psi can be used for many quarter-mile systems on level land. LEPA heads normally apply water in a bubble-shaped pattern 12 to 15 inches in diameter, but they can be set to spray to germinate seed, pre-plant irrigate or apply chemicals.

Combined savings in fuel costs resulting from lower pivot pressure and reduced operating time (LEPA can apply the same amount of effective water in less time) usually will pay the cost of converting an existing center pivot to LEPA in 1 to 3 years. The extra cost to equip a new center pivot is usually regained in 1 year or less. LEPA should be strongly considered when buying a new center pivot.

Water application rates are higher with LEPA irrigation because water is applied over a smaller area of soil. Runoff will likely occur, especially on clay soils, without furrow dikes, deep chiseling in the furrow or other tillage practices to improve the water infiltration rate of the soil. Farming in a circle helps control runoff by holding water in the furrow and is strongly recommended for all center pivots. Circular farming is essential when growing corn irrigated with LEPA because the heavy growth causes the LEPA bubblers to ride up in the corn stalks when dragged across straight rows.

Inches of water applied to the smaller wetted soil surface areas using LEPA irrigation are described in Table 4. These rates are representative of quarter mile center pivots that deliver 800 GPM with LEPA drops spaced 80 inches apart. The high rate of water application, especially with LEPA applicators in bubble position, indicates the need to use tillage practices that improve soil water intake rates.

Table 4. Inches of water applied to wetted soil surface and equivalent irrigation (inches) applied to total area as a function of center pivot speed with maximum single nozzle water delivery of 8 GPM. 800 GPM delivered to mainline 1,300 feet long (10-foot end section). 122 acres. LEPA nozzle spacing 80 inches.

Time to Complete circle			Diameter of wetted soil surface		
Days	Hours	End tower* Speed-ft/hr	Bubble 15"	Spray 80"	Equivalent irrigation
1	24	338	1.9	0.35	0.35
	36	225	2.8	0.5	0.5
2	48	169	3.7	0.7	0.7
	60	135	4.7	0.9	0.9
3	72	113	5.6	1.1	1.1
	84	96	6.5	1.2	1.2
4	96	84	7.5	1.4	1.4
	108	75	8.4	1.6	1.6
5	120	68	9.3	1.7	1.7
	132	61	10.3	1.9	1.9
6	144	56	11.2	2.1	2.1

*1,290 feet from pivot to end tower.

The rate of water application to the wetted soil surface and the equivalent irrigation amount in inches for a pivot system of any length and any LEPA nozzle spacing can be determined with the following formulas.

Acres in circle =

$$\frac{(\text{length of mainline in feet})^2 \times 3.14}{43{,}560}$$

Inches water applied =

$$\frac{\text{GPM delivered to pivot} \times \text{hours to complete circle}}{450 \times \text{acres in circle}}$$

Inches applied to wetted soil =

$$\frac{\text{Inches water applied} \times \text{LEPA nozzle spacing in inches}}{\text{Diameter of soil area wetted by LEPA nozzle in inches}}$$

To illustrate the use of the formulas, assume the pivot mainline is 1,200 feet long, LEPA nozzle spacing is 60 inches, nozzles are set to apply water in a 15-inch diameter bubble, 675 gallons per minute are delivered to the pivot and a circle is completed in 120 hours.

Acres in circle = $\frac{(1200)^2 \times 3.14}{43{,}560} = 103.8$ acres

Inches water applied =

$$\frac{675 \text{ GPM} \times 120 \text{ hours}}{450 \times 103.8 \text{ acres}} = 1.73 \text{ inches}$$

Inches applied to wetted soil =

$$\frac{1.73 \text{ inches} \times 60 \text{ inches}}{15 \text{ inches}} = 6.94 \text{ inches}$$

Note that the "inches of water applied," or equivalent irrigation, is the same as the "inches applied to wetted soil" when the diameter of the soil area wetted by an individual LEPA nozzle is the same as the LEPA nozzle spacing.

Summary

Center pivot systems offer improved water distribution and application efficiency and flexibility in managing irrigation water. Several options are available and should be considered carefully before purchasing a system. The LEPA system is a new, attractive option for improved irrigation efficiency. Correctly designed and operated center pivot systems are being used successfully by many farmers. However, a center pivot irrigation system is not necessarily the best system for every farm situation.

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