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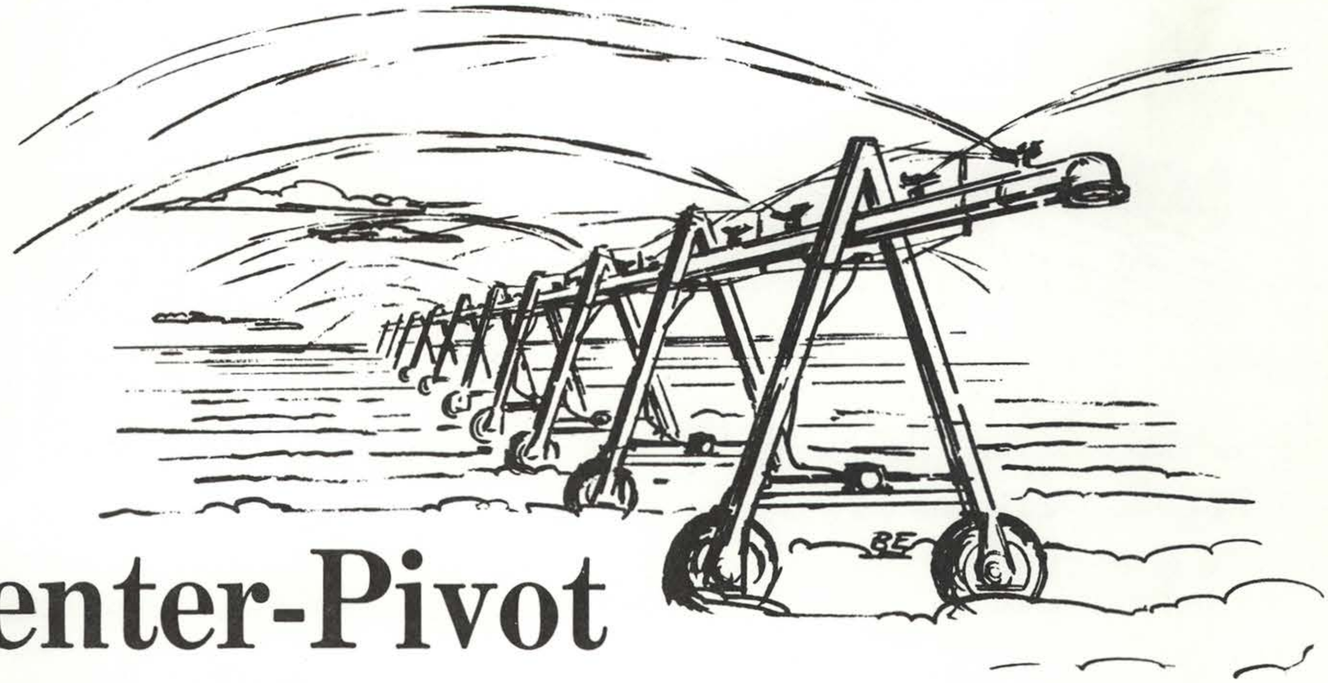

Center-Pivot Sprinkler Systems

Claude H. Pair, Dorrell C. Larsen, Robert A. Kohl

The number of center-pivot sprinkler systems is increasing in Idaho. These systems give large area coverage with low irrigation labor requirements. Center-pivots have high irrigation efficiency where adapted to crops, soil, and climatic conditions, and when used with proper irrigation management practices. In recent years these systems have become more reliable in their operation.

Purchasing Considerations

If you are considering this type of sprinkler system for your farm, investigate the suitability of your soil, equipment costs, maintenance requirements, and operating costs before signing a contract with the sprinkler equipment dealer.

You are investing in an irrigation machine that will operate more hours during a cropping season than any other piece of farm equipment. Some laterals operate 2,200 or more hours each season. The sprinkler lateral must be repairable in the field because another lateral cannot be quickly substituted for a disabled one. It must be capable of rapid repair in case of breakdown, because on shallow soils, or on fields that have not been well watered, a crop can be lost or severely damaged if the lateral is inoperable for two or three days during the peak water use period.

Therefore, it is important to choose a center-pivot lateral that has been mechanically proven to operate on soils similar to yours, and to select a dealer who has the parts and services to repair the lateral rapidly if breakdowns occur. A new center-pivot lateral seldom needs repair parts, but a source of repairs will be needed for many years after purchase.

Soils

Soils—their topography, water-holding capacity, and infiltration rate—are among factors controlling the success of a center-pivot sprinkler operation. Very coarse, coarse, and moderately coarse textured soils usually have infiltration rates exceeding the application rate of a 1300-foot center-pivot lateral. The infiltration rate of medium-textured soils should be measured because if the application rate of the center-pivot lateral exceeds the soil infiltration rate, a shorter lateral should be used or extra runoff prevention practices will be needed.

Moderately fine and fine textured soils, along with peats and mucks, are seldom suitable for a quarter-section center-pivot lateral unless the soil is level so there is no water runoff.

Where wet soils do not support the weight of the wheels and deep ruts are cut, filling the ruts with sand has provided a temporary solution to prevent stalling of the lateral. If the soil becomes sticky as well, the lateral may bog down if the land becomes too wet.

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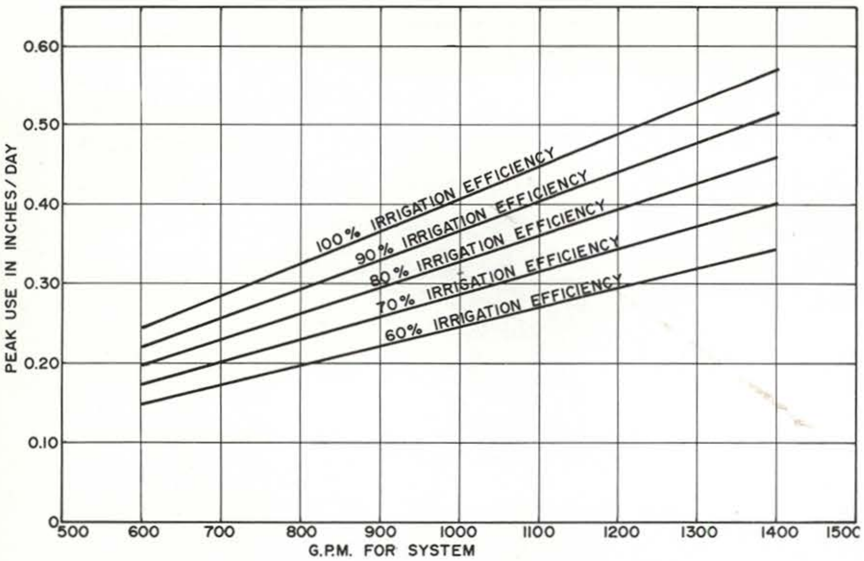

Fig. 1. Water needed for center pivot system irrigating 130 acres.

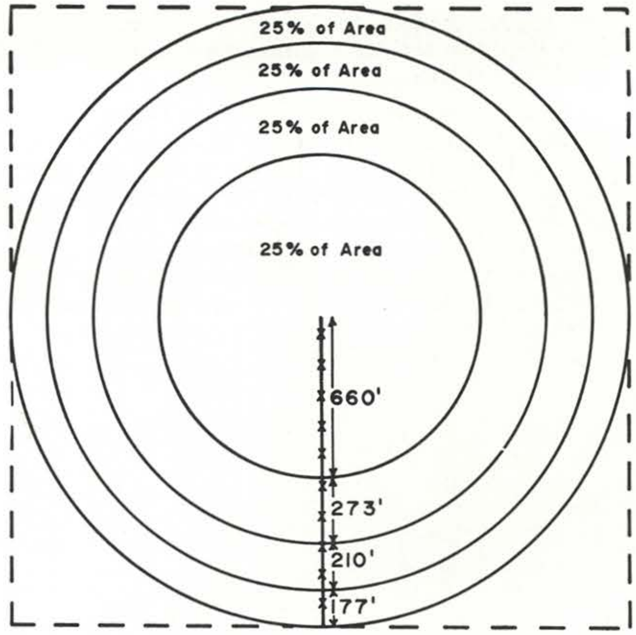

Fig. 2. Water application along lateral.

System Operation Characteristics

Capacity

A center-pivot system should have the capacity to meet peak crop requirements for the area in which it is used. Table 1 gives the peak crop requirements of several crops by location in Idaho. Fig. 1 shows the water capacity needed by a quarter-section center-pivot system irrigating 130 acres for various irrigation efficiencies and peak daily crop requirements. Irrigation efficiencies of most operating systems range from 70 to 80 percent, depending on the uniformity of water distribution along the center-pivot lateral.

As an example, consider a center-pivot system to irrigate a quarter-section of potatoes in the Twin Falls area. The peak crop water requirement is 0.31 inch per day. If irrigation efficiency is 75 percent, this center-pivot system would require a capacity of 1,000 gallons per minute.

Water Application Rates

The rate water is applied to the soil by a center-pivot system varies from a low near the pivot to very high at the outer end. Fig. 2 illustrates the reason for this variation. With a 1,320-foot lateral, water is applied along 660 feet of lateral to irrigate the center one-fourth of the area, while the outside one-fourth of the area is irrigated by 177 feet of lateral. The time of water application also varies with the longest time of application at the pivot and the shortest time at the outer end of the lateral. Because of these two factors, the rate of water application must be much greater toward the outer end of the lateral than at the pivot end. Table 2 shows the average application rate measured at points along a center-pivot lateral. The rate of water application remains the same at these points regardless of the rotation speed of the center-pivot lateral because application rate is determined by sprinkler type, nozzle size, nozzle pressure, and sprinkler spacing.

Table 1. Peak consumptive use rates in Idaho in inches per day.

Area	Alfalfa	Corn	Grain	Pasture	Potatoes	Sugar Beets
Bonners Ferry	0.25	0.22	0.22	0.22	0.24	---
Caldwell	0.33	0.28	0.30	0.29	0.31	0.30
Council	0.29	0.25	0.26	0.25	0.28	0.26
Dubois	0.28	0.24	0.25	0.24	0.27	0.25
Grand View	0.34	0.30	0.31	0.30	0.32	0.31
Grangeville	0.29	0.25	0.26	0.25	0.28	0.26
Idaho Falls	0.29	0.25	0.26	0.25	0.28	0.26
Lewiston	0.34	0.29	0.30	0.30	0.32	---
Moscow	0.29	0.25	0.26	0.25	0.28	---
Pocatello	0.30	0.26	0.27	0.26	0.29	0.27
Twin Falls	0.33	0.28	0.29	0.28	0.31	0.30

Depth of Water Application

The depth of water applied by a center-pivot system depends upon the application rate and the speed of rotation. When the application rate is held constant, then the application depth is increased as the speed of rotation is decreased. For example, if a lateral completing a rotation in 12 hours applies 0.25-inch depth of

Table 2. Average water application rate measured along a center-pivot lateral.

Distance from pivot	Average application rate
ft	in/hr
95	0.21
185	0.22
275	0.25
365	0.35
455	0.35
545	0.39
635	0.43
725	0.45
815	0.45
905	0.53
995	0.65
1,085	0.72
1,175	0.81
1,265	0.83

water per rotation, the same lateral would apply 1.0-inch depth when its rotation speed is reduced to 48 hours per rotation.

Since each sprinkler serves a larger area as its distance from the center pivot increases, uniform application depth along the lateral is difficult to achieve. Many manufacturers rely on the computer to determine nozzle size and spacing needed to apply the same depth of water along the lateral. Water distribution tests sometimes show that water is applied unevenly. Watch the soil moisture level, wetting depth and crop response for uneven distribution. Should this problem occur, request assistance from your dealer.

Types of Systems

A center-pivot system consists of a single sprinkler lateral that has one end anchored to a fixed pivot structure. The other end is continuously moved in a circle around the pivot structure. Water is supplied to the lateral through the pivot. Laterals vary in length. The lateral is supported by carriages or towers located every 80 to 250 feet along its length. The supports move on two wheels, tracks, or skids. The mechanism for propelling the lateral around the circle is mounted on each support structure. The lateral is kept straight by an alignment system that speeds up a lagging support carriage or reduces the speed of one that gets ahead. Should the alignment system fail and any support carriage get too far out of alignment, a safety device stops the whole system automatically before the lateral can be damaged.

There are four methods of powering a center-pivot sprinkler system:

1. Hydraulic water drive
    a. Piston type
    b. Sprinkler type
2. Hydraulic oil drive
3. Electric drive
4. Air drive

The hydraulic water drive systems use water from the sprinkler lateral to power a hydraulic piston on each support carriage. The piston then turns the support wheels using a ratchet mechanism. The sprinkler drive uses spinner sprinklers mounted on a shaft, which powers the wheels of each support carriage through a gear train, or by a chain and sprocket mechanism. Operating pressures at the pivot for all water hydraulic drive systems range from 70 to 100 p.s.i. Normally a water-powered system can be moved only when sprinkling.

The hydraulic oil drive has an electric, gasoline, or propane motor-driven oil pump at the pivot that maintains 600 to 1,200 p.s.i. oil pressure in the oil supply line. The oil supply and return flow pipelines extend from the pressure pump to the piston drive units located on each support carriage in most systems.

The electric systems have drive motors of ½, ¾, 1, or 1½ hp mounted on each support carriage. Most systems require 440-480 volt 3-phase, 60-cycle power. The control circuits are usually 24 or 110 volts.

The air-drive system has an electric, gasoline, or propane motor-powered air compressor that supplies air under pressure through a pipeline to piston-type driving units mounted on each support carriage.

About This Publication . . .
This is a joint contribution from the Agricultural Research Service, USDA, and the University of Idaho College of Agriculture. Claude H. Pair is Agricultural Engineer and Robert A. Kohl is Soil Scientist, both with the Snake River Conservation Research Center, Kimberly. Dorrell C. Larsen is Extension Irrigationist, University of Idaho Cooperative Extension Service, headquartered at Boise.

Costs

A complete center-pivot sprinkler lateral costs from $18,000 to $30,000 for a quarter-section system, which will irrigate 130 to 135 of the 160 acres. These prices include the center-pivot, lateral pipeline, supports or towers, propulsion and control equipment, and sprinklers. Transportation costs from the factory to the installation site add $600 to $700 per lateral, and the installation cost for assembly of all parts into an operating system costs about $1,000.

If an electrically driven center-pivot is purchased, buried electrical power lines must be installed from the commercial power source to the pivot point, electrical control and driving system. This costs from $2,000 to $2,500 if the commercial power source is on the edge of the quarter-section to be irrigated. If power has to be brought into the site from a greater distance, the cost will be higher. This all adds up to an installed cost of $150 to $250 per irrigated acre for the irrigation equipment, and does not include the main water supply pipeline, pump, motor, and water supply source.

Operational Costs

Labor, maintenance, power costs, and interest on operating capital are the operating costs to consider when comparing center-pivots with other types of irrigation systems. Labor is needed to grease, check, repair, start, and stop the moving lateral in accordance with crop water needs. Increasing the number of revolutions made by the lateral per year will increase the labor and maintenance costs. Table 3 estimates annual operating costs of a center-pivot system, assuming that the water is available for pumping at the center-pivot.

Overhead

Overhead costs include depreciation, interest on investment, and insurance. Depreciation is calculated on a

Table 3. Costs of center-pivot sprinkler system.*

	Cost/acre	
	Low	High
Initial center-pivot lateral cost	$150.00	$250.00
Annual operational costs		
Labor	$ 2.00	$ 3.00
Power	6.00	8.00
Maintenance	3.00	5.00
Interest on operational capital	.30	.40
Annual overhead costs		
Depreciation	15.00	25.00
Interest on investment	7.50	12.50
Insurance	.50	.75
Total annual costs	$ 34.30	$ 54.65

* Costs do not include the water supply pipeline, pump, motor, or water.

10-year lateral life. Interest is calculated at 10 percent on the average investment for the life of the sprinkler lateral. Table 3 shows a range of overhead costs for a quarter-section system irrigating 130 acres. Costs for water supply development or water delivery to the pivot point are not included.

Operating the System

The success of any center-pivot sprinkler depends on the design, installation, and operation of the system. Correct design and installation should be the responsibility of the manufacturer, distributor, and dealer. Correct operation is the responsibility of the farmer or his irrigator.

Most manufacturers provide an operator's maintenance manual that gives detailed steps necessary to prepare the center-pivot system for operation at the beginning of each irrigation season, the maintenance necessary during operation, and the things that should be done to prepare the system for long periods when it is not used. This manual should be obtained and used by every operator.

Each year, before the irrigation season begins, the sprinkler system should be thoroughly inspected for needed repairs and maintenance, and to see that all system parts operate properly. All moving parts that require lubrication should be greased with the correct grade, type, and amount of lubricant. The operation manual usually lists lubrication specifications. Sprinkler heads should be examined and repaired or replaced if they are not operating satisfactorily. Any leaks in the lateral pipeline should be repaired. On electrically powered machines, the use of a pressurized spray contact cleaner to clean contact points on electrical controls may prevent system shutdown later in the season. **CAUTION:** Make sure all electrical power is disconnected from the system before cleaning any electrical contact points.

System management includes timing applications to meet crop water requirements and soil-water storage capacity. Before planting, irrigate to fill the root zone with moisture. Check water penetration depth by digging holes in several locations to be sure the soil is wet throughout the crop root zone.

Crop water use is less during the early and late season than in the middle of the season. The sprinkler system is designed to apply water at the peak use rate when operating continuously. For early and late season irrigations, operate the system intermittently. Apply enough water to connect with the subsoil moisture. When the lateral returns to the starting point, check the soil to see if enough water has been used to warrant starting the lateral around again.

Anticipate crop water needs. Be sure to have the soil profile full of water before peak use begins to avoid disaster in the event of a breakdown for a day or more, especially on low water-holding capacity soils. During peak use season, check water penetration following each irrigation. If wetted depth decreases dramatically, seek assistance to correct the problem.

The irrigator must be careful in operating the system when freezing temperatures occur. At these times, ice may accumulate on the sprinkler lateral pipeline and supporting structure. This can rapidly overload and collapse the system.

Center-pivot System in Use

Some circular center-pivot sprinkler systems have been used in rugged topography. However, operations are more troublefree on level lands and on uniform sloping lands with slopes up to 10 percent. Undulating topography usually produces more operating difficulties, especially where runoff occurs. Bridges may be built across the drainageways, irrigation canals, and other small depressed areas to permit passage of the lateral supports.

Center-pivot systems operate best on soils with high infiltration rates that absorb water at the point of impact. If water is applied to sloping lands faster than the soil can absorb it, the excess water runs off, resulting in poor crop irrigation and soil erosion. Runoff also will collect in low areas and bog down the sprinkler system's wheels, tracks, or skids.

Some manufacturers recommend that lateral speed be increased to the highest possible rate when center-pivot sprinklers are used to irrigate low intake rate soils. The theory is that the soil will absorb water faster because the smaller application will occur on a section of the soil water intake vs. time curve where the intake rate is higher. Thus high application rate center-pivot machines may be able to operate on Idaho's silt loam soil. In many cases this theory has not worked because the soil intake rate was too slow to absorb the needed depth of water in such a short application time. Water applied by the lateral and retained in the soil did not equal crop needs between rotations.

Because a fast rotation speed means more miles per tower for a season's use, maintenance costs and system wear can be expected to increase as rotation speed increases.

Research is underway on methods to reduce runoff from center-pivot systems installed on soils with low intake rates. One method includes the installation of small dikes between the rows, a few feet apart, to form basins that keep the water where it falls, allowing it to be absorbed into the soil. Installation and tractor driver discomfort are disadvantages. Straw mulching offers a possibility, but the extent of its usefulness on different soil types has not been investigated. Contour planting offers another possibility of delaying runoff.

An alternative method would be to reduce the application rate by shortening the lateral length. However, two 40-acre center pivots cost about the same as a 160-acre system.

A properly designed center-pivot sprinkler system will give excellent irrigation when installed on soils with infiltration rates matching or greater than the lateral's water application rate and when operated to meet crop water needs. Poor results are likely when the system is used on sloping soils having low infiltration rates.

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