Compiled and Edited
by
Sprinkler Irrigation Association
Textbook Re-editing Committee

Claude H. Pair, Editor-in-Chief
Agricultural Engineer
United States Department of Agriculture
Agricultural Research Service
Snake River Conservation Research Center
Kimberly, Idaho

Walter W. Hinz
Extension Agricultural Engineer
University of Arizona
Tucson, Arizona

Crawford Reid
Professional Engineer
South Laguna, California

Kenneth R. Frost
Professor, College of Agriculture
Department of Soil, Water and Engineering
University of Arizona
Tucson, Arizona

Published by
Sprinkler Irrigation Association
13975 Connecticut Avenue, Suite 310
Silver Spring, Maryland 20906
CHAPTER II

CONTINUOUSLY MOVING MECHANICAL SPRINKLER SYSTEMS

Sprinkler Systems
The piston on each support carriage of the hydraulic piston water-driven system is powered by water from the sprinkler lateral pipe. The operating piston activates a set of trojan bars which in turn engage wheel lugs to turn the support wheels (Figure II-3).

A rotating, reaction-type motor assembly mounted on a shaft of the rotary water drive systems drives the wheels of each support carriage through a gear train or by a chain and sprocket mechanism as shown in Figure II-4. Operating pressures at the pivot for drive systems range from 60 to over 120 psi. In each case the water consumed by the drive unit is discharged to the crop, either directly by the spinner or by other means.

An electric motor or internal combustion engine-driven oil pump and oil reservoir at the pivot (Figure II-5) maintains 600 to 2,000 psi oil pressure in the oil supply line to drive the hydraulic oil systems. The oil supply and return flow pipelines extend from the oil pressure pump to the piston drive units or to a rotary motor located on each support carriage in most systems. If a piston is used, it actuates a set of trojan bars which engages wheel lugs to turn the wheels. If a rotary motor is used, the power is transferred to the wheels through a chain and sprocket drive combination.

The electric motor drive systems have motors of 1/2, 3/4, 1, or 1-1/2 hp, mounted on each support carriage. Most systems operate with 440- to 480-volt, 3-phase, 60-cycle electric power. The control circuits are usually 110 volts. Electrical power is supplied by an engine-driven generator, located at the center pivot, or by an underground cable which conveys the electric power from a commercial source to the center pivot. A slip ring connector at the pivot point connects the power source to the moving lateral wiring. The drive motors turn the carriage support wheels by the use of a chain and sprocket mechanism or through a gear drive as shown in Figure II-6.

The Center-Pivot System was first patented in 1949. This type consists of a single sprinkler lateral with one end anchored to a fixed pivot structure and the other end moving in a circle about the pivot. Water is supplied to the lateral at the pivot point. The lateral is supported by towers and cables or trusses which move on wheel, track, or skid support units located 80 to 250 feet apart along its length. Lateral lengths vary from 200 to 2,600 feet.

The lateral is kept in a straight line as it moves around the pivot point by an alignment system that speeds up or reduces speed of support units or stops and stops movement of the support units as required to maintain alignment. Should the alignment system fail and support units get too far out of alignment, a safety device automatically shuts down the entire sprinkler system before the lateral can be damaged. A mechanism for propelling the lateral is mounted on each lateral support structure.

The five types of power units for propelling a center-pivot sprinkler system are:

1. Hydraulic water drive
   a. Piston
   b. Rotary
2. Hydraulic oil drive
   a. Piston
   b. Rotary
3. Electric motor drive
   a. Piston
   b. Rotary
4. Air-pressure drive
   a. Piston
   b. Rotary
5. Mechanical or cable drive
The air drive systems have a heavy duty compressor driven by either the pumping plant power unit or an auxiliary power unit which supplies compressed air to a cylinder and torsion bar drive mechanism that turns the carriage support wheels. A safety valve releases air pressure and stops the system if a carriage gets stuck or too far out of alignment.

Early center-pivot sprinkler systems had laterals with rigid pipe couplings. These were satisfactory for use on level or uniformly sloping lands, but on rolling land, pipe breakage could result. Now, manufacturers supply laterals with flexible pipe couplings (Figure II-7) which can be used on rolling land.
The diagram shows the percentage of area and lateral length affected by different widths of water application. The table provides the time of water application and the length along which the water is applied. The area distribution for uniform water distribution is also mentioned. The application rates are given for different diameters of water application.
Medium-sized sprinklers with various size nozzles along the lateral have the next highest application rates because the width of coverage is about 90 feet along the lateral. These sprinkler systems usually have lower operating pressures than do systems with large sprinklers. The manufacturer recommends 50- to 60-psi pressure for best operation of medium-sized sprinklers. A 65- to 75-psi operating pressure is usually required at the pivot point.

Lowest water application rates can be obtained with laterals employing small to large sprinklers. On a 1,300-foot center-pivot lateral, the end sprinklers wetted an area of approximately 175-foot diameter. The manufacturers of the larger sprinklers recommend from 70- to 90-psi pressure for best sprinkler operation and drop size distribution. Operating pressures at the pivot point range from 75 to 110 psi to give the best water distribution and droplet size. Table II-2 shows the average water application rates along a 1,265-foot center-pivot lateral having different size sprinklers and 1,000 gpm lateral discharge.

<table>
<thead>
<tr>
<th>Distance from pivot</th>
<th>Average application rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft</td>
</tr>
<tr>
<td>95</td>
<td></td>
</tr>
<tr>
<td>185</td>
<td></td>
</tr>
<tr>
<td>275</td>
<td></td>
</tr>
<tr>
<td>365</td>
<td></td>
</tr>
<tr>
<td>455</td>
<td></td>
</tr>
<tr>
<td>545</td>
<td></td>
</tr>
<tr>
<td>635</td>
<td></td>
</tr>
<tr>
<td>725</td>
<td></td>
</tr>
<tr>
<td>815</td>
<td></td>
</tr>
<tr>
<td>905</td>
<td></td>
</tr>
<tr>
<td>995</td>
<td></td>
</tr>
<tr>
<td>1085</td>
<td></td>
</tr>
<tr>
<td>1175</td>
<td></td>
</tr>
<tr>
<td>1265</td>
<td></td>
</tr>
</tbody>
</table>

The measured peak application rate between the two outside towers for two center-pivot systems, one having all medium-sized sprinklers and the other having variable size sprinklers, gave 2.5 and 1.4 inches per hour, respectively, for a 5-minute time period. The laterals were both the same length and applied 900 gpm.

The Design of a Circular Center-Pivot System follows the general steps given in Chapter III for obtaining the basic data needed. Design capacity of a center-pivot lateral is calculated from the peak water use rate of the main crop, the area irrigated, and the water application efficiency when the system is operated continuously during the period of peak water use rate.

Crops and climate determine the peak water use rate for an area. Methods of determining crop requirements and peak rate of use are described in Chapter IV.
The effluent must be exposed to the air to oxidize.
For regularly irrigated areas, the system shall have the capacity to meet the peak moisture demand of each and all crops irrigated within the area for which it is designed. However, if the purchaser deems that an amount of water less than necessary to meet peak demand is desirable, then the design capacity will be that stated by the purchaser in writing.

Assuming that the water application rate pattern of a center-pivot lateral is elliptical, Dillon, Hilier, and Vitteto\textsuperscript{e} have developed the following formula to estimate the maximum application rate:

\[
h = \frac{122.5 \times Q}{R \times r}
\]

where \(h\) is the maximum application rate of the last few sprinklers in inches per hour, \(R\) is the wetted radius of the center-pivot sprinkler lateral in feet, \(r\) is the wetted radius of the last few sprinklers on the lateral in feet, and \(Q\) is the center-pivot system capacity in gpm.

In some sloping areas where the application rate may exceed the soil intake rate, contour or cross-slope farming, basins between crop rows, or tillage practices may be used to retain water at point of application and prevent runoff. Water runoff is more of a problem on sloping or rolling lands. Level lands usually do not have the runoff problem.

The average gross depth of water applied by a center-pivot system during each revolution depends upon the area irrigated, capacity, and time needed to complete one lateral revolution and can be calculated by the following equation:

\[
d = \frac{Q \times H}{A \times 453}
\]

where \(d\) is gross water applied in inches, \(Q\) is the flow at the center pivot in gpm, \(H\) is the time of one lateral revolution in hours, and \(A\) is the area irrigated in acres.

Operation of the System. The success of any center-pivot sprinkler is dependent on the proper design, installation, and operation of the system. The design and installation should be the responsibility of the manufacturer, distributor, and dealer. The correct operation is the responsibility of the farmer or his employee. See Chapter XI for additional operation and maintenance suggestions.

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, maintenance necessary during operation, and the steps that should be taken to prepare the system for long periods when it is not in use. This manual should be obtained and used by every operator.

Each year, before the irrigation season, the sprinkler system should be thoroughly inspected for needed repairs, maintenance, and proper operation of all system parts. All moving parts that require lubrication should be greased with the correct type, grade, and amount of lubricant. Usually, the operator's maintenance manual will give the lubrication specifications. Sprinkler heads and nozzles should be examined and repaired or replaced so midseason repairs will not be required. 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 contacts 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 the timing of water applications to meet crop requirements and necessary soil water storage. The center-pivot system is designed to apply water at a peak use rate when operating continuously. At times during the season, crop water consumption is less than in the peak use period of the season. During these times, intermittent operation of the system should be practiced.

Figure II-12 is the graphical solution for application rate at center of elliptical pattern.\textsuperscript{1}
The quantity of water that should be applied to the soil is determined by the rainfall depth at the site, the soil type, and the crop requirements. The following equation (1) can be used to calculate the amount of water to be applied:

\[ Q = r \times A \times T \]

where:
- \( Q \) is the quantity of water to be applied (in gallons)
- \( r \) is the rainfall depth (in inches)
- \( A \) is the area to be watered (in acres)
- \( T \) is the duration of the rainfall (in hours)

The diagram illustrates the continuous application rate of water to the soil. The application rate is plotted against time, showing how the rate of water application changes over time. The application rate is influenced by the soil type, water pressure, and the distance from the water source.
The application rate of a continuously moving straight lateral can be changed if the application rate is too high or too low for the soil water intake rate. Changing sprinkler nozzle sizes and pressures. If the application rate needs to be decreased to prevent runoff, the speed of lateral movement will need to be reduced to apply the same total depth of water. This will mean a decrease in acreage that can be irrigated by a system in a given period.

The average gross depth of water applied by a continuously moving straight lateral at each irrigation depends upon the area irrigated, the rate of water flow at the lateral inlet, and the time needed to complete one irrigation.

\[
d = \frac{QH}{453 A}
\]

where \(d\) is average gross water depth applied in inches, \(Q\) is the flow at the lateral inlet in gpm., \(H\) is the time needed to irrigate the area in hours, and \(A\) is the area irrigated in acres.

**Operation of a Continuously Moving Straight Lateral** will depend upon the brand of system, and the dealer-installer should instruct the owner in the proper procedures. One straight moving lateral has wheels on the supporting carriages that can be turned 90°. This lateral irrigates down one side of the main pipeline, after which the irrigator turns the wheels, tows the lateral across the main pipeline, straightens the wheels, and then the lateral returns, irrigating to the end of the field opposite the starting position. There the wheels are put in lateral towing position and the lateral is towed to the starting position. A small tractor is used in the towing. Figure II-14 shows the operation of the towed lateral.

Should the lateral need to be moved further than the flexible hose length, the hose will have to be disconnected from one outlet and connected to another outlet along the main pipe. This is usually done by towing the hose with a tractor, but a hose reel illustrated in Figure II-19, Chapter II, is recommended.

This type of system is dependent upon a constant lateral travel speed for uniform water distribution over a field. Some of the factors that affect its ability to maintain constant speed are the same as those that affect the traveler type system and are shown on page 26 of this chapter.

See Chapter VI for additional operating and maintenance suggestions for all parts of the system.

**TRAVELER SPRINKLER SYSTEMS**

Traveler sprinkler laterals are powered track or wheeled vehicles that tow a high-pressure, flexible hose connected to the water supply main pipeline. The vehicle is towed by a power winch and cable or propelled by its own engine across the field at regular intervals, usually 330 feet apart, irrigating as it moves. The sprinkler is typically of the large volume or boom type, operating at pressures of 80 psi or higher, delivering 300 to 1,000 gpm or more, and covering a wetted diameter of 200 to 600 feet. Chapter II, page 22, has pictures of the traveler system. Figure II-15 shows a second type of traveler.
Travelling sprinkler laterals may have a long (up to 600 feet), flat-iron header and may be set at a small incline to suit the terrain. The high-pressure hose is connected to the sprinkler on the vehicle, which is usually a truck. When the sprinkler is activated, the water is directed in a wide arc due to the high pressure, covering a large area. The system is designed to be as efficient as possible, with minimum waste of water. The travelling sprinkler is a movable irrigation system that can be moved from one field to another, making it ideal for large-scale farming operations. The flow rate of the water is calculated using the equation:

\[ Q = \frac{443 \times E \times A}{E_H} \]

where \( Q \) is the flow rate in gpm, \( E \) is the crop evapotranspiration rate (inches per day), \( A \) is the area irrigated in acres per day, and \( E_H \) is the irrigation efficiency in percent.

The travelling sprinkler is a versatile irrigation system that can be adapted to different field geometries and topographies, making it a popular choice in irrigated agriculture.
the number of hose and vehicle moves required.

The travel vehicle selected should perform at the needed pumping rate and have the designed travel speed range. Controls to provide uniform speed of travel and positive shutoff at the end of travel are necessary. The manufacturer should supply instructions for proper vehicle operation, maintenance procedures, and repair parts replacement.

The sprinkler should have a capacity equal to that required for the system. The application rate of the sprinkler should not exceed the intake rate of the soil being irrigated. The use of part-circle sprinklers increases the application rate. A half-circle coverage will double the application rate of the same sprinkler with full-circle coverage under the same operating conditions. Some sprinklers need to be operated with part-circle coverage to give even water distribution, a dry path for vehicle travel, or both. The application rate of a sprinkler does not vary with the travel speed of the vehicle, but total depth of water applied does depend upon travel speed.

The use of lower trajectory sprinklers in high wind conditions will get maximum distance of throw and a minimum of pattern distortion. Higher trajectory sprinklers are used for low wind conditions to obtain maximum distance and breakup of stream.

where \( h \) is the average application rate in inches per hour, \( Q \) is the sprinkler capacity in gpm, and \( r \) is the sprinkler wetted radius in feet. This average application rate is increased if the sprinkler is not operated full circle. The average application rate obtained in Equation [8] is divided by the percentage of a full circle wetted expressed as a decimal.

The selection of hose size for a traveler type system should be made on the basis of the pressure loss that can be tolerated. The capacity of the system can be used as a guide for selecting the diameter from Table II-3.²,⁷ The pressure loss for various size and diameter hoses is shown in Table II-4.

### TABLE II-3
Guide for Selecting Irrigation Hose Size for Traveling Sprinkler Systems²,⁷

<table>
<thead>
<tr>
<th>System acreage</th>
<th>System capacity, gpm</th>
<th>Recommended irrigation hose diameter, inches</th>
<th>Standard full length, ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 20</td>
<td>Up to 150</td>
<td>2.5</td>
<td>330, 500 or 660</td>
</tr>
<tr>
<td>20 to 40</td>
<td>150 to 300</td>
<td>3</td>
<td>660</td>
</tr>
<tr>
<td>40 to 100</td>
<td>250 to 600</td>
<td>4</td>
<td>660</td>
</tr>
<tr>
<td>60 to 120</td>
<td>400 to 750</td>
<td>4.5</td>
<td>660</td>
</tr>
<tr>
<td>80 to 160</td>
<td>500 to 1000</td>
<td>5</td>
<td>660</td>
</tr>
</tbody>
</table>

### TABLE II-4
Estimated Pressure Loss in psi for Irrigation Hose when Operated at about 100 psi³

<table>
<thead>
<tr>
<th>Nominal Inside Diameter, inches</th>
<th>Pressure loss in psi/100 feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>3.4</td>
</tr>
<tr>
<td>4</td>
<td>3.6</td>
</tr>
<tr>
<td>5</td>
<td>5.1</td>
</tr>
<tr>
<td>6</td>
<td>6.0</td>
</tr>
<tr>
<td>7</td>
<td>7.2</td>
</tr>
<tr>
<td>8</td>
<td>8.5</td>
</tr>
<tr>
<td>9</td>
<td>9.6</td>
</tr>
<tr>
<td>10</td>
<td>10.7</td>
</tr>
</tbody>
</table>

Footnotes:
²,⁷ variation in materials and broadcast conditions

Figure II-17.

Typical application pattern of traveler system.

The water application rate to the soil from a traveler sprinkler is determined by the sprinkler discharge and the sprinkler pattern, since usually only one sprinkler is involved. See Figure II-17 for an application pattern for a traveler and a "set" sprinkler. An equation used to calculate the average application rate for full-circle coverage is:

\[
 h = \frac{96.3 Q}{\pi r^2} \]
This figure illustrates the application of the principles of the Treadwheel System to the design and manufacture of a modern Treadwheel. The Treadwheel System is based on the principle of counter-rotation, which ensures that the treadwheels rotate in a coordinated manner, thus providing a smooth and efficient propulsion mechanism. The system is characterized by its ability to maintain a constant speed of the treadwheel, regardless of the load applied. This is achieved through a combination of mechanical and hydraulic components, which work in tandem to ensure optimal performance.

The Treadwheel System is designed to be modular, allowing for easy assembly and maintenance. It is also highly adaptable, allowing for customization to suit various applications and environments. The system is particularly well-suited for use in areas with limited space, such as in urban settings or in areas with restricted access to traditional transportation systems.

In conclusion, the Treadwheel System represents a significant advancement in the field of transportation technology. Its unique combination of mechanical and hydraulic components, along with its modular design, make it a versatile and efficient solution for a wide range of applications. With continued research and development, the Treadwheel System has the potential to revolutionize the way we think about transportation systems.
Sprinkler systems are being used for the application to land of liquid wastes from cities, towns, farms, and industrial plants in many parts of the United States and abroad. In the United States, over ten years of experience has led to widespread use, rapidly increasing since 1967 with the explosion of Environmental Protection programs and legislation on the national, state, and local levels.

Public Law 92-500 prohibits the discharge of polluted water to any river, lake, or underground water supply in the entire nation. Sprinkler irrigation offers an excellent solution wherever location, the many economic and technical factors make its use feasible.

Private owners are better able to apply the sprinkler technique and are doing so at a much faster rate than public agencies. They partly because of the scattered locations and special problems, and partly because they are under more pressure from regulating authorities.

The following is a partial list of potential users of sprinkler irrigation systems for waste-water land treatment:

- Food processing plants
- Paper, hard-board, and related industries
- Mobile home parks
- Hotels, motels, and restaurants
- “Coin-Op” laundries and car washers
- Chemical plants
- Oil refineries
- Metal processing plants
- Campgrounds and parks
- Schools and institutions
- Golf courses and other recreational facilities
- Power plants for dust removal and disposal
- Cement and ore handling plants

Treated liquid wastes are more acceptable for land treatment if this method is most widely used. Treatment ranges from simple screening to primary and secondary treatment, removal of oil, grease, metals, harmful chemicals, pH adjustment, and chlorination.

REFERENCES CITED


Chapter III

LAND APPLICATION OF LIQUID WASTES

This chapter written by: Lewis W. Barton, Lewis W. Barton Co., Haddonfield, New Jersey.