

MECHANIZED SPRINKLER SYSTEMS, THEIR APPLICATIONS AND  
LIMITATIONS — WHAT NEXT?

Claude H. Pair, P.E.  
USDA-ARS-SWC  
Northwest Branch  
Snake River Conservation Research Center  
Kimberly, Idaho  
Idaho Agricultural Experiment Station cooperating

The mechanization of sprinkler irrigation systems for more efficient irrigation with reduced labor began soon after the first systems were installed near the beginning of this century. Milo B. Williams (2) documented this statement when he wrote: "Engineers have devised systems of piping and special spray equipment for irrigating all areas by spray methods and have introduced automatic devices which reduce labor." This paper will discuss the mechanization of sprinkler irrigation to date and give some possible future trends.

Williams (2) described three types of spray irrigation systems that were adopted for field irrigation by 1917. Mechanization of the third system, "overground spray lines fed from an underground feed pipe," was described as follows:

"The original overhead system consisted of a few lengths of steel pipe set on parallel rows of posts and connected to a hand force pump. A series of small holes was drilled in the shell of the pipe, through which water could be forced in the form of spray. . . . The idea was conceived of replacing the holes with small brass nozzles which could be screwed into the pipe shell. . . . It was found that by placing one row of nozzles in a pipeline which could be turned or rolled in bearings, a strip of land 50 feet wide could be irrigated by turning through a total arc of about 90°. . . . Machines for turning the nozzle lines backward and forward are being perfected and seem to be desirable for special conditions where night irrigation is practiced or spray is used for frost protection, as in Florida."

Sprinkler system mechanization moved forward very rapidly from this early beginning as the availability of farm labor for irrigation decreased, and as aluminum equipment was developed, and more efficient pumping units became available. The sprinkler industry has responded to the farmers' needs for reducing irrigation labor requirements by introducing a large number of mechanical move systems.

A complete sprinkler system may consist of the following parts: a water source; a pumping plant including pump, motor, or engine and protective devices; a main line; sub-mains; and sprinkler laterals. Some systems also have booster pumps and water supply canals. Mechanization has been greatest on the sprinkler laterals, but the pumping plant has been mechanized in at least one system.

Because of mechanization, today's farmer has a choice of nine major types of sprinkler systems and many versions of each type. These types are handmove, tow lines, giant sprinklers, side roll, side move with and without trailer line, center-pivot self-propelled, straight lateral self-propelled, traveler, and solid set systems.

### Handmove Portable Lateral System

The handmove portable lateral system is composed of either portable or buried main line with valve outlets at various spacings for the portable laterals. These laterals are of aluminum tubing with quick couplers and have either center-mounted or end-mounted riser pipes with sprinkler heads. This system is used to irrigate more area than any other system, and it is used on almost all crops and on all types of topography. A disadvantage of the system is its high labor requirement. This system is the basis from which all of the mechanized systems were developed.

Mechanization of handmove systems was tried using a pipe rack built on a trailer. After each irrigation, the trailer was pulled through the field alongside the sprinkler lateral. Each section of lateral pipe was disconnected and placed on the pipe rack by hand. The trailer with pipe was towed to the next lateral position, where the pipe was unloaded and reconnected. Poor traction for moving the trailer, soil compaction, and crop damage were some of the problems encountered with this mechanization attempt. Some pipe trailers are used today to place handmove laterals in the field at the beginning and remove them at the end of the irrigation season.

Another mechanization attempt was the development of a machine that would pick up the disassembled portable lateral pipe sections and move each section to the next setting where the lateral was reassembled by hand and placed into operation. Few of these machines were used in the field.

One modification made to the handmove system to reduce labor is the addition of a tee to each sprinkler riser which is used to connect a 50-foot, 1-inch diameter, trailer pipeline with a stabilizer, and another riser with sprinkler head at the end. This modification reduces the number of handmove laterals by half; however, the system is more difficult to move than the conventional handmove lateral.

### Tow-line System

Lateral mechanization continued by fixed or swivelled two-wheeled carriages or skid pans being attached to the handmoved pipelines at intervals of 40 to 60 feet along the lateral to form a tow-line system. The lateral is then end-towed by truck or tractor from one set to the next. Many of these systems are used to irrigate pasture and hay crops where traction is better for the towing vehicle.

### Giant Sprinkler Systems

The giant sprinkler system may consist of one or more sprinklers discharging from 100 to several hundred gallons per minute over an area 200 feet or more in diameter. Originally this system was an enlarged version of the ordinary field sprinkler, but now it may involve a rotating boom with multiple nozzles having boom arms up to 125 feet long on each side of the bearing pivot. The giant

sprinklers have been mechanized by mounting the sprinkler on a two- or four-wheeled trailer for easy movement by truck or tractor. The early systems had portable quick connector main pipelines to convey the water from the source to the sprinkler. In recent years the pipelines have been replaced with high-pressure flexible hose. The giant sprinkler systems are used on alfalfa, pasture, corn, sugarcane, and other tall crops. High winds cause more water distribution problems with this type of sprinkler than with the smaller conventional sprinkler.

### Side Roll Systems

Handmove laterals were further mechanized when wheels were clamped around the coupler end of each section of lateral pipe and the lateral side-rolled from one setting to the next by hand. A power unit was then installed in the center of each lateral to mechanically move it from one set to the next. The first power units used hand-operated bicycle pedals, lever ratchet, or foot-powered mechanisms. Today, one or more gasoline engine-powered movers are used to move a quarter-mile of side roll lateral. These mover units require the irrigator to walk considerable distances to disconnect the sprinkler lateral from the main line outlet, start the gasoline engine, and move and reconnect the lateral to the main line outlet. To further reduce the labor requirements, equipment was developed to operate the mover units from the mainline end of the side roll lateral. These end-move devices include a gasoline engine-driven shaft with a power takeoff mechanism at one or more locations along the side roll lateral. The portable engine in this system can be used to move several laterals.

Another mover unit for side roll systems uses an electric motor in place of the gasoline engine. The electric motor is powered and controlled from a tractor-powered electric generator or engine-driven electric generator mounted in a truck.

A third mover unit for side roll systems has a hydraulic mover mounted on and powered by the tractor. The mover is connected to the outlet end of the side roll lateral and by a combination of the torque action of the hydraulic mover and the movement of the tractor, the side roll lateral is rolled from one set to the next. Heavy gauge aluminum tubing is used in parts of this system.

As a further step in the mechanization of sprinklers, a balanced head sprinkler riser was developed for use on side roll systems so that regardless of the position in which the lateral pipe stops when being moved from one setting to the next, the sprinkler head will be in correct position for best water distribution. Before use of this riser, the lateral had to be straightened by hand to achieve best water distribution.

The most recent development in mechanization of the side roll equipment is the trailer line with sprinkler that makes one side roll lateral equivalent to two laterals, thus reducing equipment and labor costs. A patented coupler is used to connect the lateral pipeline between wheels. The coupler has a rotating section supported by nylon rollers that allows the lateral line to rotate and tow the trailer lines when moving from one set to the next.

Side roll sprinkler systems are limited to low growing crops. Also, their operation becomes more difficult as the topography becomes more rolling, although such systems have been used on extremely rough topography. Side roll systems must be securely anchored when not in use to prevent damage from their being blown across the field.

## Side Move Systems

Sprinkler irrigation of tall crops such as corn caused further mechanization of sprinkler systems. The lateral pipeline with sprinklers attached is supported above the crop at 50- to 60-foot intervals with a tandem two-wheeled carriage arrangement. Each wheel is driven by a belt, chain-drive, or gear mechanism from a line shaft that runs the length of the lateral. The line shaft is powered at the middle of the lateral by a small 6- to 10-horsepower gasoline engine. Another system uses electric motors to power sections of the line shaft. A motor generator mounted in a truck furnishes the power for motor operation. A control panel mounted on the motor generator frame is used to individually control five motors to achieve alignment of the quarter-mile lateral. Trailing pipelines 1 to 2 inches in diameter are attached to the lateral pipeline on some systems. From 1 to 9 sprinklers are mounted on each trailer line, making the 9-sprinkler trailer line system equivalent to 10 hand-move laterals. Outrigger stabilizers are used on the trailer lines to increase the stability of the sprinkler riser and improve water distribution. The stabilizers may be placed on each riser, on the end riser, or on the trailer line itself. Adjustable carriage wheels, or an extra set of wheels, allows the side move lateral to be end-towed from one field to another, using a truck or tractor. The trailer pipelines are carried on a rack attached to the lateral pipeline carriages during this moving process.

The latest development in the mechanization of side move systems is the addition of self-aligning equipment. This enables the operator to align long laterals while the system is moving. Alignment was a problem when moving some of the older models in this type of sprinkler system.

## Center-Pivot Self-propelled Continuously Moving Systems

Mechanization of sprinkler laterals continued by anchoring one end of the lateral pipeline and connecting it to the water supply at the center of the irrigated area. The lateral is continuously moved in a circle around this central pivot point. The lateral is supported on two-wheeled tracks, or skid-supported towers usually spaced at 80 to 250 feet apart along the lateral. The lateral length ranges from a few hundred feet to 2,000 feet or more, and one revolution around the field requires 8 hours to 7 days. The towers along the lateral are kept in position by an alignment system that speeds up a lagging tower or reduces the speed of one that gets ahead. Should the alignment system fail and any tower get too far out of line, the whole system automatically stops before the lateral can be damaged.

There are four methods of powering the center-pivot self-propelled sprinkler systems:

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

Early laterals had rigid pipelines with limited flexibility, but flexible joints at intervals along the pipeline now allow the circular center-pivot systems to be used on more rolling topography.

Center-pivot self-propelled sprinkler systems require fields free from any obstructions above ground in the area irrigated, such as telephone lines, electric power poles, buildings, and trees. They are best adapted for use on soils having a high intake rate, and on uniform topography. When used on soils with low intake rate and irregular topography, the runoff resulting causes erosion and wet areas that may interfere with the uniform movement of the lateral around the pivot point. Where these systems are used on square land subdivisions, some means of irrigating the four corners must be provided, or other uses made of the area not irrigated. In a 160-acre quarter-section subdivision, about 30 acres are not irrigated by the center-pivot system.

### Straight Lateral Self-propelled Continuously Moving Systems

Manufacturers are investigating mechanization of the sprinkler lateral pipeline to provide a straight lateral self-propelled continuously moving system. Systems that are being marketed or being tested for marketing have the pipeline supported on two-wheeled self-propelled carriages at intervals of 40 to 80 feet along the lateral. A high-pressure flexible hose connects the lateral to the main pipeline. The drive power for past systems and recent prototypes is water hydraulic. An alignment mechanism is used to keep the various carriages moving in line across the field. Should trouble develop, the safety devices will stop the system, thus preventing damage to the sprinkler equipment. Speed of lateral movement is adjustable from 2 to 6 feet per minute.

Straight, self-propelled lateral systems are just beginning to appear on the sprinkler equipment market, and many changes will be made before this equipment becomes standardized. This type of sprinkler system requires rectangular fields free from obstructions for most efficient operation. Measured water distribution from these systems has shown the highest uniformity coefficients of any system for single irrigations under windy conditions.

### Traveler Systems

Giant sprinkler systems were mechanized to convert them into a continuously moving sprinkler by use of a powered winch mounted on the wheeled sprinkler carriage or stationed at the other end of the field from the sprinkler carriage. By winding up the cable, the sprinkler and connecting high-pressure hose are towed across the field. The sprinkler, hose, and cable are then moved to another set and the cable unreeled across the field for the trip back across the field.

The winch may be powered by a water turbine using the flow of water to the sprinkler, or by a small gasoline or bottled-gas engine. Some systems have engine-driven reels to roll up the flexible hose for transportation to the next place of use. Roller guides or capstans are used with some traveler systems, around which the flexible hose is dragged to the next sprinkler set.

The most completely mechanized sprinkler system has one or more giant sprinklers, pressure pump, ditch guidance mechanism, and portable dam all mounted on a 4-wheeled engine-powered tractor-type vehicle that straddles

an open water-supply ditch. In operation, the traveling portable dam is dragged in the water-supply ditch and forms a pumping pool. Water is pumped under 75 to 125 p.s.i. pressure for discharge through the sprinkler or sprinklers. The machine moves down the ditch, sprinkling water as it goes. When it reaches the end of the ditch, control equipment automatically stops the machine until the portable dam, pump suction screens, and the guidance mechanism are raised and the sprinkling machine driven to the next supply ditch. Strips 330 feet wide are irrigated with each trip across the field. Level or very gently sloping fields are required for this type of system.

The traveler-type systems are used in tall growing crops and areas needing supplemental irrigation. Problems encountered with this type of sprinkler system are inadequate soil water intake rate and wind. The minimum application rate of these machines is from 0.35 to 0.40 inch per hour. Runoff will occur on soils having intake rates smaller than this. Wind distorts the pattern from the giant sprinklers, so they are not recommended for use in extremely windy areas.

### Solid Set Systems

A solid set sprinkler system has enough lateral pipe and sprinkler heads so that none of the laterals need to be moved for irrigation purposes after being placed in the field. There are four types of solid set systems: (1) the portable lateral, (2) the buried or permanent lateral, (3) the sequencing valve lateral, and (4) the moving lateral.

The portable lateral system is used for potatoes and other high-value crops where the system can be moved from field to field as the crop rotation or irrigation plan for the farm is changed.

Moving the laterals into and out of the field requires much labor. This has been mechanized by the use of special trailers on which the portable lateral pipe can be stacked by hand. After a trailer has been properly loaded, the pipe is banded in several places to form a bundle, which is lifted off the trailer at the farm storage yard with a mechanical lifter. The procedure is reversed when returning the laterals to the field for the next season.

The buried or permanent lateral is placed underground 18 to 24 inches deep with only the riser pipe and sprinkler head above ground. Many systems of this type are used in citrus groves, orchards, and other farm fields.

The sequencing valve lateral may be buried, on the soil surface, or suspended on cables above the crop. The heart of the system is a valve on each sprinkler riser that turns the sprinkler on or off when a control signal is applied. Most systems use a pressure change in the water supply to activate the valves. This system is mechanized by use of an automatic controller that can be programmed to operate the necessary main line valves or pump to make the pressure changes for operation of the sequencing valve at the sprinklers.

A moving solid set lateral system now being tested consists of laterals 2,300 feet long, having pipe 1 to 1-1/2 inches in diameter, with sprinklers spaced every 330 feet. Each lateral is connected to the main pipeline by a 200-foot length of flexible high-pressure hose. The lateral is pulled 330 feet by a hydraulic oil-operated winch. This winch can be programmed to pull the lateral at the rate of 2 to 6 feet per hour. When the end of the laterals

reaches the winch side of the field, a cable latch is released and each lateral is towed 330 feet back to its starting point at the far side of the field by a tractor or truck. The two advantages of this system over the conventional solid set system are lower cost and better water distribution on each irrigation.

The portable lateral, buried or permanent lateral, and sequencing solid sets are being automated by the use of electric or air controlled valves activated by controllers. These automatic controllers are programmed for irrigation, crop cooling, and frost control. Some systems are activated by soil moisture measuring and temperature sensing devices.

### Future Sprinkler Systems

The mechanization of sprinkler systems is resulting in the introduction of many variations of the nine types of systems previously discussed. When this search for the perfect sprinkler system is completed, there will remain three basic types of systems: (1) the handmove, (2) the straight moving self-propelled lateral, and (3) the automatically controlled solid set.

The handmove system will be used on low value crops and on rough, irregularly shaped areas if labor and mechanical equipment are available for moving the laterals. The lateral construction will differ little from that used today.

The straight moving self-propelled lateral will be in wide use because it will give the best water distribution pattern each irrigation under all wind conditions. The supporting mechanism for the lateral pipeline will be a bridge truss with wheels that run on tracks mounted every 330 to 660 feet apart along the lateral, depending on the land topography. The truss and moving mechanism also will be used for land preparation, planting, cultivating, and harvesting. This type of construction will give a minimum of soil compaction in farm operations and result in better crops. The guidance mechanisms and safety devices will insure that the moving lateral will not get out of its assigned travel path under any conditions. Jules Billard (1) pictures a similar type of system in his article entitled "The Revolution in American Agriculture."

The solid set systems will contain buried main and lateral pipelines. The risers and sprinkler heads will be retractable below the ground level so that land preparation, seeding, cultivating, and harvesting may be done without damage to or interference from the sprinkler irrigation system. The sprinkler system will have automatic adjustable nozzle sizes so that it can be used for frost control, environmental control, or irrigation, when needed. The system will be used for the application of fertilizers, and pesticides. Where frost protection and environmental control are desired, the solid set system gives the best control.

Both the straight moving self-propelled lateral sprinkler system and the solid set system will be automatically controlled by a computer which is programmed to use soil moisture, moisture stress in plants, weather data, crop and stage of growth, availability and amount of water information to start the irrigation, frost protection, or crop cooling cycles for the farm to produce the maximum of quality crops.

Today's agriculture sprinkles about 20 percent of the irrigated area in the United States. As water supplies become more critical, this is expected to increase to at least 80 percent.

## SUMMARY

Mechanization of agricultural sprinkler irrigation systems began over 60 years ago and is continuing at a rapid rate that will eventually produce the ultimate in sprinkler systems for the agriculture of the future.

Nine basic types of systems are available on the market: handmove, tow lines, giant sprinkler, side roll, side move with and without trailer lines, center-pivot self-propelled, straight lateral self-propelled, traveler, and solid set systems. The mechanization in each system type is described.

The percentage of irrigated land in the United States that is sprinkled is expected to rise from today's 20 percent to 80 percent in the future because more efficient use of our available irrigation water supplies will be required.

The number of types of sprinkler systems is expected to decline to three: handmove, straight moving self-propelled lateral, and solid set. The latter two types will be automatically controlled through computers programmed to use soil moisture, moisture stress in plants, weather data, crop and stage of growth, availability, and amount of water information to start the system for irrigation, frost control, or modification of the microclimate in the field.

## REFERENCES

1. Billard, Jules B. The revolution in American agriculture. National Geographic 137(2):184. February 1970.
2. Williams, Milo B. Spray Irrigation. USDA Bulletin No. 495, February 14, 1917.