Converting Sprinkler Systems to Lower Pressure

Sprinkler irrigation presently accounts for about 4,500,000 acres of irrigated land in the Pacific Northwest. Center pivot systems are used on about 1,250,000 acres. Almost 100% of sprinkler irrigation systems in the Pacific Northwest use electric energy as their source of power. During the past decade, electric energy rates have increased sharply. Even though irrigation costs are still one of the lesser costs of production, irrigators have sought and adopted practices that reduce pumping costs.

Several factors affect energy use in sprinkler irrigation—total amount of water pumped, pumping depth, pumping plant efficiency, and system pressure. *Reducing the system operating pressure* is one economically effective cost-reduction measure.

Low-pressure sprinkler systems

A low-pressure sprinkler system is one that has been converted or modified to operate satisfactorily with a lowered pressure at the sprinkler heads. Examples are fixed-spacing sprinkler systems—solid sets, hand moves, and side rolls—operating at about 35 psi (pounds per square inch) and moving systems—center pivots and linear moves—operating at pressures down to 20 psi at the last tower or outer ends.

Potential for saving energy

When converting a sprinkler system to low pressure, the energy savings are accomplished only by the reduction in sprinkler pressure, assuming that total volume of water applied and overall pumping plant efficiency remain constant after conversion to low pressure (this should be the case). The energy and dollars saved are easily calculated, and the total savings can then be compared to the installation or retrofitting cost to determine if the conversion is economically worthwhile. Use the following equations:

Energy savings:

$$\text{kWh} = \frac{A \times in \times psi \times 0.2}{E}$$

kWh = energy savings in kilowatt hours
A = acres in field
in = inches of water applied per season
psi = pressure reduction at sprinkler in pounds per square inch
0.2 = conversion factor constant
E = overall pumping plant efficiency (decimal)

Dollar savings:

Annual cost savings equals kWh saved times cost per kWh

$$\$ = \text{kWh} \times \text{rate}$$

Example: An irrigation system on a 40-acre alfalfa field has operated at 55 psi at the sprinkler. After conversion, the system operates at 35 psi. The annual gross irrigation application is 18 inches. The overall pumping plant efficiency is 70% and electric energy price is $.04 per kWh.

Note that overall pumping plant efficiency (E) varies for each installation. For this example, an overall pumping plant efficiency of 70% is assumed. This would be a good to excellent efficiency for a small centrifugal pumping plant but only a fair to poor efficiency for a large turbine or deep-well pumping plant.

$$\text{kWh} = \frac{A \times in \times psi \times 0.2}{E}$$

$$\text{kWh} = \frac{40 \times 18 \times 20 \times 0.2}{.70}$$

$$\text{kWh} = 4114$$

$$\$ = \text{kWh} \times \text{rate}$$

$$= 4114 \times \$.04$$

$$= \$164.56 \text{ per year}$$

Making the conversion

The conversion to low pressure requires installing low-pressure nozzles or sprinkler heads and modifying the pump to match the new operating pressure. The replacement low-pressure nozzles or sprinklers should be sized to discharge the same flow rate as the existing nozzles. A complete set of matching nozzles is recommended for fixed-spacing systems such as solid sets, hand moves, and side rolls. New low-pressure sprinkler packages are recommended for center pivots.

The new system pressure must be selected carefully. Just reducing the pressure by the difference in sprinkler pressure requirements may not be advisable. After the conversion, head losses in individual mainlines and laterals will be the same as before the conversion. The rule-of-thumb for high-pressure systems allowed the pressure drop in a lateral to be 20% of the total pressure. For low-pressure systems, allowable pressure variation is more critical to good flow distribution, thus the rule-of-thumb for these systems is a 10% allowable pressure drop.

After the conversion, the total pressure may be only half of what it was previously. The pressure drop may now be 40% of the total, allowing a 23% variation in flow rate between the head and far end of a lateral. This uniformity problem in fields with large elevation variations can be eased by adding about 5 psi to the after-conversion system pressure and using pressure regulators, although this will limit the energy savings.

It may not be practical to convert water-drive center pivots or travelling big guns since high pressures are needed for locomotion.

If the nozzles or sprinklers are replaced without modifying the pump to reduce operating pressure, the system will put out a greater flow rate than previously (figure 1) and will likely use more energy. To realize energy savings, the pump must be modified by either trimming the impellers or, in the case of a deep-well turbine, dropping off one or more turbine bowls. The original electric motor can be used since underloading the motor will cause no harm and motor efficiency will generally be maintained.

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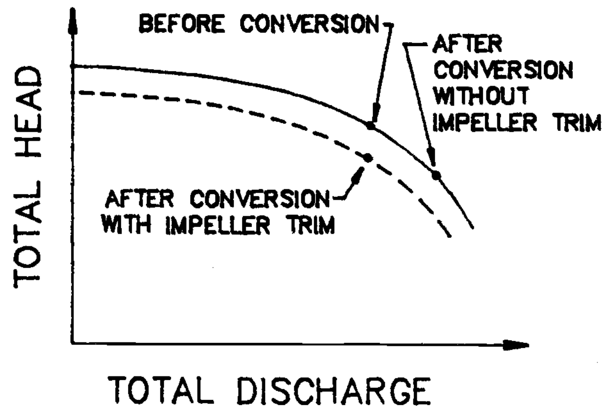

Figure 1.—Pump must be modified to establish new performance curve to give desired pressure and discharge rate after converting to low-pressure sprinklers.

Systems using internal combustion engines connected directly to pumps can accomplish the pressure reduction by throttling back engine speed, thus reducing pump speed.

Results of low pressure conversion

The primary purpose of a low pressure conversion is to reduce the energy required by the irrigation system. Unfortunately, reducing operating pressure affects more than just pumping costs. Reducing the system pressure can lead to one or more of the following problems: sprinklers may not throw water as far, droplet size may increase, and pattern shapes of individual sprinklers may change. This can cause application rates on moving sprinklers to be higher, the uniformity on fixed-spacing sprinklers to decrease, and potential runoff to generally increase. Increased droplet size can cause soil surface compaction due to the greater impact energy of larger drops.

Moving sprinkler systems such as center pivots and linear moves with low pressure can still have good uniformity due to their continuous motion. The potential for evaporation loss from sprinklers may drop slightly with lower pressure. On the other hand, wind-drift losses become greater with spray heads on center pivots.

Alleviating the problems

There are several things that can be done to relieve some of the problems created by converting to lower pressure. One is using sprinkler nozzles that employ unconventional orifice configurations. These sprinkler nozzles have oval, square, or odd-shaped orifices which cause better breakup of the stream at low pressure than conventional circular orifices while maintaining a good individual sprinkler pattern.

The use of sprinkler lateral offsets can also help reduce the poorer uniformity on fixed-spacing sprinklers. Offsets offer a simple and inexpensive way to compensate for the low-pressure pattern reduction without changing spacing on hand-set or side-roll systems. Offsets cut the lateral spacing in half when used on two successive irrigations. The use of offsets or swinglines on low-pressure conversions can actually make possible a more uniform water distribution than was originally obtained with the high-pressure nozzles on 40 × 50 foot or 40 × 60 foot spacings.

When low-pressure spray heads are used on center pivot systems, water application rates can be reduced by placing the spray heads on booms to widen the application pattern.

Runoff can be controlled by using smaller sprinklers and more laterals on fixed-spacing systems, using booms, conservation tillage, or reservoir tillage. The low end pressures on center pivots means that it is not possible to use large sprinklers on the end of the machine to cover the corners unless an end gun booster pump is used.

When converting systems to be used on rough terrain, it is recommended that pressure-regulating devices be used because the pressure changes involved in going up and down hills are much larger relative to the new, lower total-operating pressure now being used (see figure 2). In addition, it will be necessary to maintain proper system pressure at the highest point in the field plus about 5 psi extra to operate the pressure regulators.

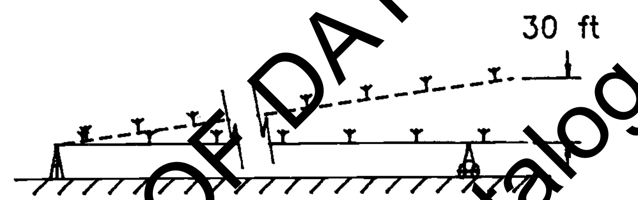

Figure 2.—A system with 60 psi end pressure on level ground will drop 20% in pressure and 10% in flow rate when encountering a 30-feet rise. The same system with 20 psi end pressure on level will drop 65% in pressure and 40% in flow rate on a 30-foot rise.

Net benefits

The energy cost savings that can be achieved by reducing system pressure are available to offset the costs of new low-pressure nozzles or sprinkler packages and/or reworking the pump. These total energy cost savings and the cost of retrofitting should be carefully analyzed. Any change in the irrigation system must be well thought out to avoid expensive mistakes.

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