SPRINKLER SYSTEM CONVERSIONS

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Irrigators using existing center pivots may be interested in changing sprinkler packages for a number of reasons: to take advantage of new sprinkler technology, to overcome a poor design on the original package, to reduce energy requirements, or simply to replace worn out sprinklers.

Whatever the reason, there may be multiple benefits in changing a sprinkler package on an existing center pivot. Many systems will benefit significantly in decreased energy use as a result of changing from a high pressure to medium or low pressure. Other systems may realize an increase in application efficiency by changing to a sprinkler package that has lower evaporation losses. Systems with insufficient capacity may actually show crop yield increases as a result of this increased application efficiency.

In any case, there are considerations that should be investigated before converting to a new sprinkler package. The new sprinkler package should be appropriate for the crop, soil and topographical characteristics of the site. The information presented here deals with the system oriented concerns that may result when changing a sprinkler package. The irrigation system includes the center pivot, the pumping plant, and their components. Changing the operation of one component could affect the overall effectiveness of the system.

EFFECT OF PRESSURE REDUCTIONS

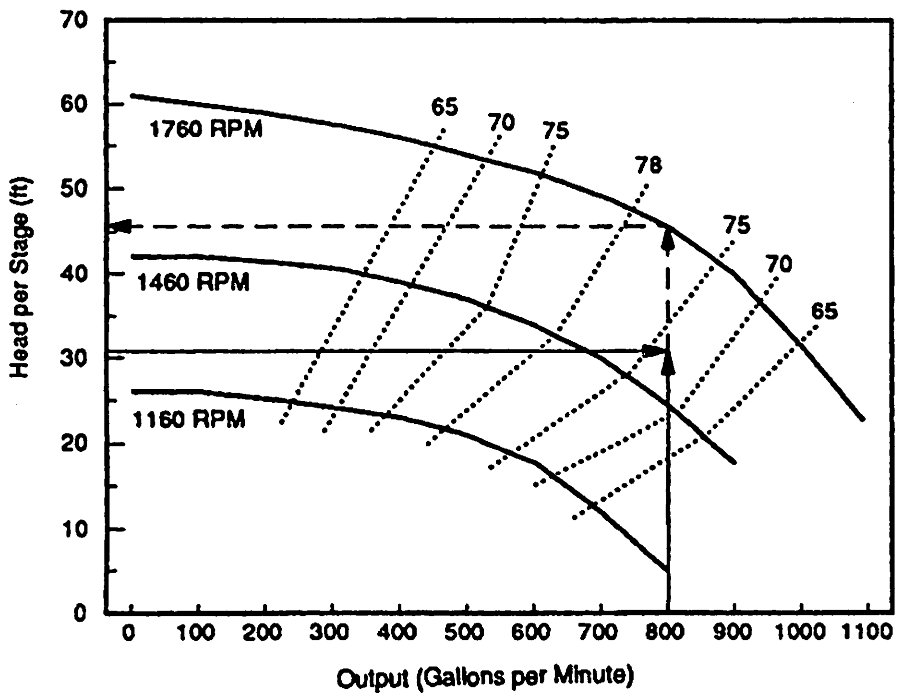
Reducing the operating pressure of a center pivot system should reduce operating costs, but there are some pitfalls. When the sprinkler pressure is reduced, other system components may need to be altered. In some cases, the short term costs of making these changes may seem excessive. However, making those changes may be the only way to reap the benefits that should result from lowering the sprinkler operating pressure.

One potential problem associated with reducing the system pressure involves operation of the end gun. Systems with existing end guns may not have adequate pressure to operate the end gun after the pressure reduction. Some systems could require the addition of a booster pump and/or a smaller end gun. Others may require that an end gun no longer be used. An end-gun booster pump may have additional power and maintenance requirements. In addition, removing the end gun will decrease the irrigated acreage by 10 to 20 acres.

When converting to a low-pressure system, irrigated acreage may be lost even if the original system did not have an end gun. The high pressure impact sprinkler has additional radius of throw from the outermost sprinkler in the range of 75 to 100 feet. Replacing this package with a low to medium pressure system with a wetted radius of 20 to 50 feet could result in a substantial loss of irrigated acreage. For example, if the wetted radius was reduced by 50 feet on a 1,320 foot center pivot, the irrigated acreage would be reduced by 10 acres.

Another consideration is the impact of reduced operating pressure on water application uniformity. Medium to low pressure sprinklers will be more sensitive to pressure variation due to field elevation changes than high pressure sprinklers. To overcome this sensitivity and insure that the uniformity of application is not sacrificed, many systems will require pressure regulators on each sprinkler. Pressure regulators require that the pipeline pressure be 2-5 psi greater than the design pressure for the sprinkler/nozzle. If the flow rate passing through the nozzle varies by more than 10% due to elevation differences, pressure regulators should be considered.

Figure 1. Pump curve showing the effect of decreasing the engine speed.

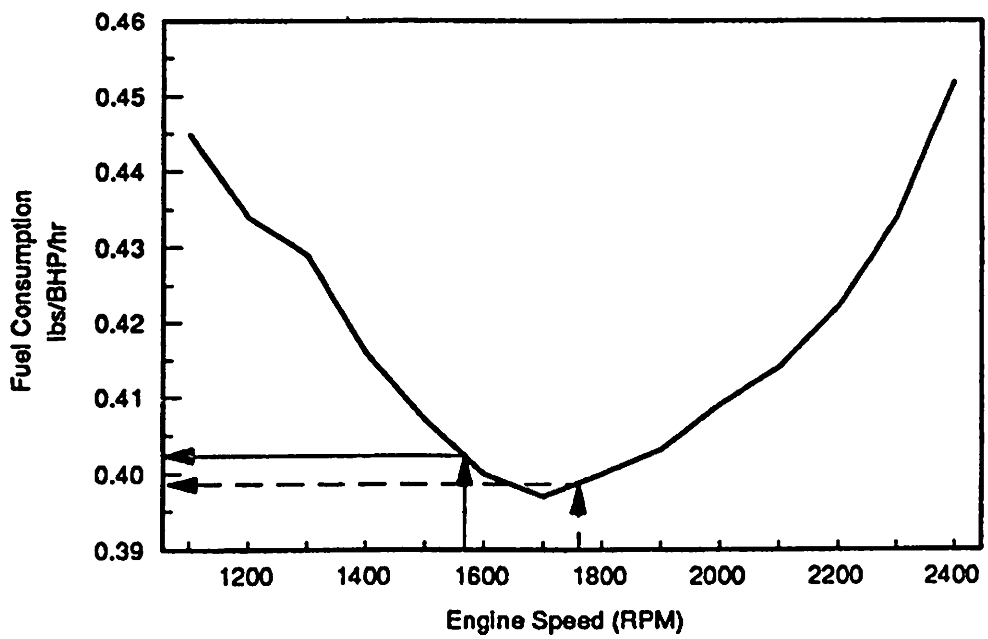


CHANGING OPERATING PRESSURE -- Internal Combustion Units

An example of this is shown in the pump performance curve of Figure 1. The relationship between pressure developed by each stage or pump bowl and gallons per minute of output is shown by the solid lines. Note that individual curves are presented for three pump speeds. If the pump is operating as it was designed, it will operate somewhere along the solid lines as long as the speed does not change. When the speed changes, the pump operates on a new performance curve as shown by the three curves. The dotted lines, which are roughly perpendicular to the solid performance curve lines, indicate the pump efficiency at that point. Pumps can operate below and/or to the left of the performance curve if they are worn or out of adjustment. Keep in mind that the speed used on a pump curve (Figure 1) is pump speed, not engine speed. Pump and engine speed will be equal only if 1:1 gear ratio is used in the gear head, or if the engine/motor is directly coupled to the pump drive. Reducing the engine speed will reduce the operating pressure and flow rate.

The application amount will remain the same with the lower pressure system if the flow rate and travel speed of the center pivot are not changed. The application rate (the rate at which water is added to any point on the soil surface) will probably increase, because the lower pressure system will have a smaller wetting pattern.

Figure 2. Engine performance curve, showing the effect of engine speed on fuel consumption.



One potentially negative effect of changing the engine speed is that the pump efficiency will change. This could mean that a lower percent of the energy delivered to the pump shaft is effectively converted to water movement. If this change in efficiency is large, reductions in energy use associated with reducing the pressure may be offset by the increase in energy use associated with the decrease in pump efficiency. As a result there may be no overall savings in energy costs. In fact, the energy costs may increase. One solution to this problem is to replace or modify the pump bowls and\or impellers.

When engine speed is changed, the engine fuel use must also be considered. Internal combustion engines are designed for maximum efficiency at a given speed. Deviation from that speed will increas the engine fuel consumption, as shown in Figure 2. If the increase in fuel consumption is significant, it would be better to change the gear head and maintain engine speed while reducing pump speed.

CHANGING OPERATING PRESSURE -- Electrical Units

Many electrically powered pumps are driven by vertical hollowshaft motors that are directly coupled to the pump lineshaft. There is no way to change the rotational speed of the pumps when using electric motors.

One option to reduce the output pressure of electrically driven pumps is to continue to use the original pump and design the sprinkler package to deliver more gallons per minute at a lower pressure. If we return to Figure 1, you'll note that if the pump speed remains the same (@1760 rpm) and the operating pressure is reduced from 45 feet per stage to 30 feet per stage, the flow rate will increase to about 990 gpm. Thus, the impeller output will stay on the curve for 1760 rpm and move downward to the right. Note also that the pump efficiency decreases by about 11 percent in the process. This shows graphically why some installations will require changes in the pump to obtain all benefits of reducing the operating pressure.

Another outcome of simply reducing the operating pressure and nozzle for the new flow rate is that system flow rate directly impacts the peak water application rate of the system. The combination of increased flow rate and decreased wetted radius of the sprinkler package increases the peak water application rate of the system. Increasing the application rate too much could result in surface runoff.

Another option is to pull the pump and remove one or more stages from the bowl assembly. This is a viable option if the pump design is well matched to the volume to be pumped through the new sprinkler package or if the pump requires maintenance. Many of the older pumps have not been serviced since they were installed 20+ years ago. If the pump is questionable, this would be a good time to have the pump and bearings rebuilt.

A third alternative would be to pull the pump and trim the diameter of one or more impellers. This will establish an entirely new pump curve. Depending on the new operating conditions, it may be necessary to remove one or more impellers and trim others to obtain the desired flow rate and pressure.

A final, and the most expensive option, would be to replace the pump with a new one that is designed to operate under the new conditions. This would be desirable if the pump impellers and bowl assemblies are beyond repair.

If the motor is not too old, using the old motor would not be an operational problem since electric motors only draw the current required by the load. New motors operate more efficiently than some older motors. So replacing an older over-sized motor with a new motor may be economical. One problem with over-sized electric motors is that many utility companies assess a demand charge based on the rated horsepower of the motor. An over-sized motor will have a unnecessary demand change unless the utility company uses a demand meter to assess demand charges.

RUNOFF POTENTIAL

Low to medium pressure systems may generate runoff that could overshadow lower operating costs. One of the criteria for irrigation is that all portions of the field receive a minimum depth of water. Thus, when runoff occurs, additional pumping time will be necessary to insure that the areas of the field are fully irrigated. Runoff is influenced by peak water application rate, which is influenced by wetted diameter and system flow rate. The wetted diameter of low to medium pressure systems is considerably less than high pressure systems. Converting to lower pressures may increase the water application rate enough to generate unacceptable runoff amounts. To reap the benefits that lower pressure systems can deliver, carefully match water application characteristics with field soils and slope conditions.

One option that could eliminate the potential for runoff is to combine a reduction in system flow rate with the reduction in operating pressure. If the system capacity is greater than needed to water the crop adequately, this option will directly reduce the peak water application rate of the system at the same time operating pressure is reduced.

COST CONSIDERATIONS

There are many cost-related factors that must be considered when making a change in sprinkler packages. Table I summarizes the potential costs and benefits associated with the change. For any system, it should be determined that the benefits will outweigh the costs before the conversion is made.

Other economic factors to consider are related to the projected life of the system and its components. There is more incentive to change sprinkler packages if the currently used sprinklers should be replaced due to wear anyway. Also, any new sprinklers placed on an older center pivot may be salvaged and transferred to a new system if the center pivot itself is replaced.

Table I. Potential economic costs and benefits associated with changing sprinkler packages.

Potential Costs	Potential Benefits
Equipment - sprinklers - pressure regulators - drop tubes - booster pump - additional sprinkler outlets - new center pivot	**Reduced Fuel Costs** - reduced operating pressure - fewer hours of operation - reduced electric demand charges
Acreage Reductions - loss of end gun - reduced system wetted radius	**Application Efficiency** - increased efficiency if no runoff - reduced pumping time
Pump Alterations - bowls/ impellers removed or rebuilt - bearings rebuilt or replaced - gear head or pulley replacement	**Increased Yields** - if pump capacity was inadequate - if application efficiency increases

PROCEDURE SUMMARY

A general outline of the steps to take when deciding if a sprinkler change is warranted is given below.

1. Select sprinklers appropriate for crops, soils and slopes.
2. Determine operating pressure and flow rate needed for the new sprinkler package.
3. Evaluate the pump and power plant to determine current operating efficiency and verify its use for new conditions.
4. Total costs associated with system changes and the new sprinkler package.
5. Estimate savings associated with decreased energy use or increased crop yield.
6. Compare total costs with estimated savings over a set payback period.

EXAMPLE CALCULATIONS

An irrigator wishes to install a low pressure sprinkler package on an older high pressure center pivot. In doing so, he will need to change the pump operating pressure. He has an internal combustion engine with fuel consumption shown in Figure 2. The gear head on the well has a 1:1 gear ratio, so the engine speed equals the pump speed. The current pump curve is shown in Figure 1. Six stages are used, so all readings from the head per stage axis (vertical) of Figure 1 are multiplied by 6. The initial (high pressure) settings are:

Flow Rate	800 gpm
Pressure at Pivot Point	70 psi (161.7 ft of head)
Pumping Lift and Friction Loss	49.5 psi (114.3 ft of head)
Engine Speed	1760 RPM

The new sprinkler package requires 30 psi (69.3 ft of head) at the pivot point. First, the irrigator needs to know the new engine speed required to pump 800 gpm at the new pressure. The elevation and friction losses in the column are the same, so the total head would now be 114.3 ft plus 69.3 ft, or 183.6 ft. This is 30.6 ft of head per stage. Following the solid arrows on Figure 1 leads to a point that is approximately 1/3 of the distance from the 1,460 RPM curve to the 1,760 RPM curve, when measured perpendicularly. The new pump speed would then be approximately 1,460 plus 1/3 times the difference between 1,760 and 1,460, or 1,560 RPM.

Having both the old (dashed arrows) and new (solid arrows) points on the pump curve (Figure 1), the difference in fuel consumption resulting in the change may now be calculated. The pump efficiencies are estimated in Figure 1 based on position relative to the dotted lines (76% for the old system and 74% for the new system).

The fuel consumption rate is read from Figure 2. The brake horsepower for either case is determined as:

$$\text{BHP} = \frac{\text{total pumping head (ft)} \times \text{flow rate (gpm)}}{3960 \times \text{pump efficiency (decimal)}}$$

For the high pressure system, this is:

$$\text{BHP} = \frac{276 \times 800}{3960 \times 0.76} = 73.4 \text{ hp}$$

Diesel fuel consumption for the high pressure system at 1,760 RPM was 0.398 lb/BHP/hr (dashed arrows, Figure 2). Thus, the estimated fuel consumption rate for the high pressure system was:

$$\text{Fuel Consumption} = \frac{0.398 \text{ lb}}{\text{BHP}\cdot\text{hr}} \times 73.4 \text{ BHP} = 29.2 \text{ lb/hr}$$

For the low pressure system, the brake horsepower required is:

$$\text{BHP} = \frac{183.6 \times 800}{3960 \times 0.74} = 50.1 \text{ hp}$$

Diesel fuel consumption for the low pressure system at 1,560 RPM would be 0.402 lb/BHP/hr (solid arrows, Figure 2). Thus, the estimated fuel consumption rate for the low pressure system will be:

$$\text{Fuel Consumption} = \frac{0.402 \text{ lb}}{\text{BHP}\cdot\text{hr}} \times 49.5 \text{ BHP} = 20.1 \text{ lb/hr}$$

The difference in fuel consumption due to the nozzle conversion will be 29.2 lb/hr - 20.1 lb/hr = 9.1lb/hr or a 31% reduction (about 1.3 gallons of diesel per hour). This decrease in fuel consumption must offset the cost of the conversion when spread over the life of the new sprinkler components. Note that both the pump and engine efficiency decreased.

The question remains whether changes to the pump and motor operation would be justified. In this case, the change in pump efficiency was approximately -2 % (Figure 1). The estimated diesel fuel consumption changed by about -1 %. So changes to the pump and motor would net less than $100 per thousand hours of operation, so it is not economically feasible to make the changes unless the pump impellers, bearings or bowl assemblies justify maintenance.