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COLORADO STATE UNIVERSITY EXTENSION SERVICE

Improving irrigation pumping plant efficiencies

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Quick Facts

Most irrigation pumping plants have excessive operating costs because they use more power or fuel than they should.

Pumping plant performance can be evaluated from field tests to determine if changes are needed.

Some problems can be corrected with simple adjustments while others require expensive repairs.

Rising energy costs have increased the cost of pumping to the point that many farmers are finding irrigation to be unprofitable or only marginally profitable.

Fortunately, however, pumping costs are an item over which farmers have some degree of control. Pumping costs often are larger than need be for two reasons — 1) more water is pumped than is necessary and/or 2) the pumping plant operates inefficiently. This Service in Action sheet will consider only the second problem — inefficient pumps.

Field testing programs in Colorado, Wyoming, Nebraska and other states have shown that overall or "wire-to-water" plant efficiencies for electrically driven pumps average less than 50 percent, as compared to a realistically achievable efficiency of 67 percent. This implies that 25 percent of the electrical energy used for pumping is wasted due to poor pumping plant efficiencies alone. Therefore, farmers could reduce energy costs by as much as $2,000 per year per well by raising pumping plant efficiencies from present average levels to potential efficiencies.

There are many reasons for poor pumping plant efficiency. Some of the more common causes of unsatisfactory performance and their remedies are as follows:

1. The easiest and least expensive problem to correct is impellers that are out of adjustment. Both pumping rates and efficiency are reduced because energy is used to pump water that is recirculated around the impellers instead of being pumped into the irrigation system. Impeller adjustment is especially criticial with semi-open impeller pumps. Impellers may be out of adjustment because of improper initial adjustment or because of wear. To avoid pump damage, only experienced pump people should attempt to make impeller adjustments.

2. One of the most common reasons for poor pumping plant efficiency is the use of pump bowls that are designed for a higher pumping rate than the well can supply. Overestimating well yield often results from poor testing of the well after drilling. If well testing was inadequate, the yield of the well may have been less than anticipated. In other cases, the pump supplier recommended oversize pump bowls in order to require fewer stages, thereby reducing initial cost. Furthermore declining water tables in some areas have reduced well yields. In this situation, a pump is forced to operate at a lower flow rate and higher lift than that for which it was designed. If for any of these reasons the pump capacity does not fit the well characteristics, a high pumping plant efficiency can be achieved only by replacing the bowls with new (not rebuilt) bowls that meet the well requirements.

3. Damaged impellers also will result in poor performance. Three common causes of impeller damage are cavitation (low temperature boiling of pumped water), sand pumping and improper impeller adjustment. Sometimes only the impellers need to be changed, but more often the permanent solution is to replace the entire bowl assembly. If this is done, it is likely that a different model of pump bowls should be used to fit present well conditions.

4. Incorrect power unit selection is another major cause of low efficiency. This is much more important for engines than for electric motors. While the efficiency of electric motors does not vary greatly with loading, it should be noted that over-loaded motors have shorter lives, are less dependable and are more expensive to maintain. On the other hand, because of graduated energy costs, underloaded motors often increase the cost per kilowatt of power used.

Incorrect engine selection is a major cause of low efficiencies among the natural gas pumping

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plants. Many are overloaded. Automotive type V-8 engines often are used for applications where heavy duty industrial engines should be used. Operating speeds of the smaller engines are increased so that they will produce adequate power. As a result, they wear out rapidly and require much more fuel.

5. Failure to perform required maintenance including tune-ups is often a cause of low efficiency in engine-driven pumping plants. Electric motors, on the other hand, usually operate efficiently if they operate at all. Finally, a change in operating conditions from those for which a pumping plant was designed will result in a drop in efficiency. Three common situations that result in increased pumping lifts or pressures are a drop in water table elevation, converting from open discharge to a pipeline and changing from surface irrigation to sprinkler irrigation. On the other hand, a reduction in operating pressure results when center pivot sprinklers are converted from high pressure to low pressure in an attempt to save energy. Usually the pump will operate less efficiently under the new lower pressure conditions than it did under high pressure. As a result, anticipated savings in energy costs may not be realized.

Since some power suppliers offer field evaluation of electrical pumping plant performance at very reasonable cost, many farmers can easily determine whether or not their pumps are operating properly. Internal combustion engine driven plants are more difficult to test since both the engine and the pump should be evaluated. A few private consultants and pump suppliers are equipped to perform this service.

A field pump evaluation involves measuring several operating characteristics of the pump. These include:
- depth to water during pumping;
- pump discharge pressure;
- pump flow rate; and
- rate of electrical energy or fuel consumption.

From these measurements, both the water horsepower, or rate of useful work done by the pump, and input horsepower equivalent, or rate of energy used by the motor or engine, are calculated. Overall pumping plant efficiency is then the water horsepower divided by the input horsepower equivalent.

Once it has been found that a pump is not performing up to par, the next step is to consult a reputable pump supplier to determine the cost of repairs or replacing the pump. If it is necessary to pull the pump, these costs will be substantial.

How does one decide whether pump repair or replacement will pay off? There are certain conditions under which pump bowls will almost certainly need to be replaced, including:
- The potential well yield is adequate, but the pump will not supply the required flow rate at the required pressure.
- The water table has declined dramatically; this was not anticipated in the original pump selection.

- A major change in the irrigation system has occurred; either from surface irrigation to sprinkler irrigation or vice versa or from high pressure to low pressure sprinklers.

In other cases, the decision of whether to spend money on a pump is not so clear cut. One then needs to compare the potential savings from increased efficiency to the cost of pump improvements. The results of a pumping plant efficiency test as described earlier can be used to make this comparison. Tables 1 and 2 are provided below to simplify the necessary calculations for electrically driven pumps.

Table 1: Potential energy savings from pump improvement (kwh/ac-in pumped) assuming 65 percent efficiency after improvement.

Total pumping head (ft)*	Present pump efficiency (%)							
	25	30	35	40	45	50	55	60
50	10.5	7.7	5.6	4.1	2.9	2.0	1.2	0.5
100	21.0	15.3	11.2	8.2	5.8	3.9	2.4	1.1
150	31.5	23.0	16.9	12.3	8.7	5.9	3.6	1.6
200	42.0	30.6	22.5	16.4	11.7	7.8	4.8	2.2
250	52.5	38.3	28.1	20.5	14.6	9.8	6.0	2.7
300	63.0	45.9	33.7	24.6	17.5	11.8	7.2	3.3
350	73.5	53.6	39.4	28.7	20.4	13.8	8.4	3.8
400	84.0	61.2	45.0	32.8	23.3	15.7	9.5	4.4
450	94.5	68.9	50.6	36.9	26.2	17.7	10.7	4.9
500	105.0	76.6	56.2	41.0	29.2	19.7	11.9	5.5

To convert to metrics use the following conversion: 1 foot = .3 meter.

The potential for cost savings can be determined using Table 1. From the pump test, one determines the total pumping head (pumping lift + discharge pressure + friction loss) and the present overall pumping plant efficiency. Using the table, one then finds the potential energy savings from improving pump efficiency to a new level of 65 percent. The annual savings in energy costs is equal to the table value times the annual volume of water pumped times the unit cost of electricity.

Example #1

A certain pump supplies a center-pivot system on the High Plains that irrigates 120 acres (48 hectares) of corn and applies a gross depth of 20 inches (51 centimeters) of water per year. A pump efficiency test finds that the current overall efficiency is only 40 percent and that the total pumping head is 300 feet (91 meters). What are the potential savings from improving the pump efficiency to 65 percent if the cost of electricity is 6 cents per kwh?

From Table 1, the potential energy savings is 24.6 kwh per acre-inch pumped. The annual volume pumped is (120 acres) x (20 inches) or 2400 acre-inches. The potential savings are:

$$24.6 \ \frac{kwh}{ac\text{-}in} \ x \ \frac{2400 \ ac\text{-}in}{year} \ x \ \frac{\$.06}{kwh} \ \text{or } \$3542/year$$

The annual cost of pump improvements can be found as follows. The annual cost of an investment is equal to the initial cost times the appropriate capital recovery factor

corresponding to the life of the investment and the prevailing interest rate.

The capital recovery factor is found from the following table for several interest rates. The 10-year economic life is applicable for pump repairs while the 15-year economic life is applicable for pump replacement.

Table 2: Capital recovery factors based on varying interest rates.

Capital recovery factors

Interest Rate, %	12	13	14	15	16	17	18	19	20
10-year life	.1770	.1843	.1917	.1993	.2069	.2147	.2225	.2305	.2385
15-year life	.1468	.1547	.1628	.1710	.1794	.1878	.1964	.2051	.2139

Example #2

For the pump in the preceeding example, the bowls could be replaced at a cost of $12,000 to provide an improved efficiency level of 65 percent. Is investment worthwhile if the farmer must borrow the money at 17 percent interest?

From Table 2, the capital recovery factor for 17 percent interest and a 15-year economic life is .1878. The annual cost of the improvement is therefore

$$(\$12{,}000)\ (.1878) = \$2254/year$$

Since the potential savings found earlier ($3542/year) exeeds the cost of improvement, the investment is probably justified.

If this analysis had indicated that potential savings were significant, but somewhat less than the annual cost of the improvement, it would probably be advisable to have the pump tested again in a year or two. Pump wear and/or water table decline could easily result in the change being justified at that time.

One must remember that this analysis is based on an achievable efficiency level of 65 percent after pump improvement. If this level is not realized, neither will be the anticipated savings in energy costs. The farmer would, therefore, be well advised to obtain a written contract from the pump supplier guaranteeing a certain level of pump performance that is to be achieved by the proposed pump improvements.