Pumping Plant Efficiencies

The increasing costs of electric energy and growing concern for efficient use of that energy have focused increased attention on the operating efficiencies of irrigation pumping systems. Tests of pumping plants reveal that many are operating at unacceptably low efficiencies and, consequently, are using much more energy than necessary.

Wire-to-water efficiency

The overall or "wire-to-water" efficiency of the pumping plant is the ratio of work done by a pumping plant to the energy put into the pump. The pumping plant is defined as the pump and motor plus all associated fittings from the water source through the pump to the discharge into the irrigation distribution system. Efficiency is expressed by the following equation:

$$\text{Overall plant efficiency (\%)} = \frac{\text{gpm} \times \text{tdh} \times 100}{\text{Input hp} \times 3960}$$

gpm = flow rate in gallons per minute pumped

tdh = total dynamic head in feet created by pump (sum of pressure, lift, and all friction losses in pipes and fittings)

Input hp = power delivered to drive motor

3960 = constant to convert units to hp

Pumping plant efficiency tests

A pumping plant, whether new or old, can be tested to determine its energy efficiency and provide information on the adjustments or retrofitting needed to improve its efficiency. The pumping plant efficiency test and evaluation should be conducted by trained personnel using accurate, well-maintained and regularly-calibrated testing equipment. In most areas, this service can be performed by irrigation consulting firms, well drilling companies and electric power suppliers.

The information obtained during a pumping plant efficiency test includes the following:

- pumping water level or lift
- discharge pressure
- pumping flow rate
- friction losses encountered from water source to discharge
- energy use rate (power)
- adverse conditions which may be detrimental to performance.

Interpreting test data

Accurate measurements are needed to properly test the performance of the pumping plant, including the associated fittings from the water source to the discharge from the pump into the irrigation distribution system. Interpreting the results of a pumping plant test involves careful evaluation of various components. The efficiencies of individual pumps vary among models, manufacturers and types. Good pump efficiencies are usually in the range of 75 to 85%. The efficiencies of electric motors range from about 84% for motors under 7½ horsepower to about 92% for motors of 60 horsepower or larger. Therefore, the maximum theoretical efficiency for a good pumping plant seldom exceeds 70% when combined with other inherent energy losses in the system as shown in figure 1.

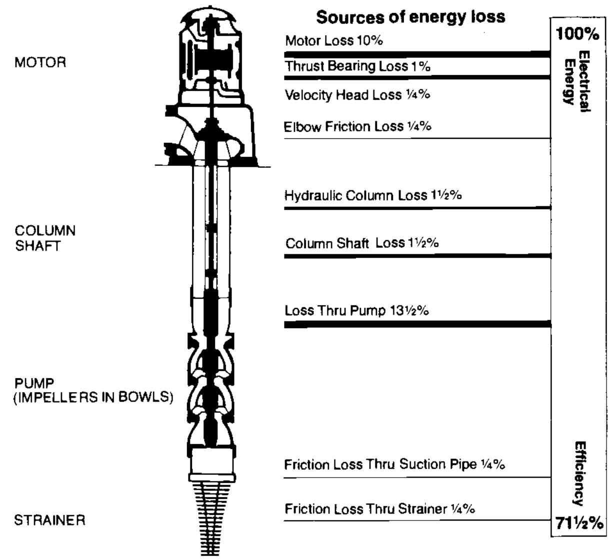

Figure 1.—An overall pumping plant operation efficiency of about 70% is maximum attainable.

A 65% wire-to-water plant efficiency is generally considered achievable, and units with less than a 55% efficiency warrant investigation to determine if modifications, repairs, or replacement should be made.

The four primary causes of low overall pumping plant efficiencies are:

1. mismatches of pump, irrigation systems, and changed depth to water source;
2. improperly designed or sized fittings;
3. pump wear due to abrasion or cavitation; and
4. poor maintenance practices.

Mismatches of pump and sprinkler system are quite common. Very often, laterals and sprinklers have been added, deleted or changed without making pump adjustments. Sometimes the pump was improperly selected for the job. Water tables may have lowered since initial installation.

Improperly selected or sized fittings around centrifugal pumps (figure 2) where water velocities are high can waste considerable energy due to friction. It is not uncommon to find that 10 to 15% of the total energy required is used just to overcome system friction losses occurring in pump fittings.

Pumps can wear over a period of time due to abrasive materials in the water and cavitation. In some areas, minerals from the water will deposit or form crusts on the impeller vanes or volute cases. Cavitation problems are often created in centrifugal pumps where required net positive suction head (NPSH) exceeds the available NPSH of the pump. All these factors reduce efficiency.

Poor maintenance practices can appreciably lower pump efficiencies. Such things as partially-plugged intake screens, air

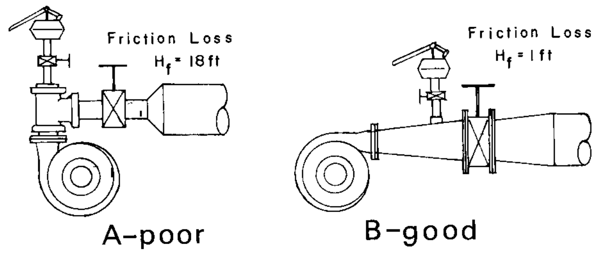

Figure 2.—Effect of inefficient and efficient fittings on friction losses, and, in turn, energy losses. Fittings with abrupt changes in direction or velocity of water flow tend to be energy hogs.

leaks in suction lines, misalignment of shafts between pumps and motors, overtightened packing glands or seals, caked-on dirt and oil on motors, obstructions over motor ventilation vents and leaky fittings all cut into good efficiency.

Corrective measures

Repairs or modifications are usually warranted when overall pumping plant efficiencies are lower than 55% For pumping plant repairs to be economically feasible, the energy savings from improved pumping plant efficiency along with the benefits from income tax deductions and depreciation must pay for the repair costs and debt incurred. A 3-year payback period for retrofitting investments is generally acceptable.

Correcting the mismatch of the pump and sprinkler system usually requires redesign of at least some part of the system. This should be performed by technically-qualified individuals. The redesign may involve trimming of pump impellers, renozzling of sprinklers, or redesign of the laterals. In some cases, it may require pump replacement in order to get the proper pump.

Replacement of improperly designed or sized fittings may be necessary to reduce friction losses. The potential energy savings is highly variable because of the many configurations of fittings used. However, the efficiency improvement can be considerable as shown in figure 2. Two guidelines for minimizing friction losses are to (1) install fittings which provide gradual rather than abrupt changes in water velocity and direction, and (2) maintain water velocity in the 2 to 3 feet per second range in the suction line and not exceeding 5 feet per second in the discharge line. The low velocity is more critical on the intake side of the pump because of its effect on pump performance.

A pumping plant can have a low wire-to-water efficiency even though the pump is functioning properly. It is very important to compare individual pump performance with the manufacturer's pump performance curve for that specific pump because performance efficiencies can vary considerably. Pumps operating within 5% of their respective pump curve are considered to be in the acceptable performance range. If a pump is operating well off the performance curve, it may be an indication of excessive wear. When this is the case, pump bowls may need adjustment or pump impellers may need appropriate trimming.

Adjusting to new flow conditions resulting from pump repair may be inconvenient on hand-move or side-roll systems since they are usually designed to operate on an 8-, 12-, or 24-hour schedule. It is difficult to change the "hours per set" because of irrigation district policies or labor management problems. Adjustments, therefore, must usually be made in the "interval between irrigations" for these systems. For systems pumping from wells, timers can be used to shut down the system after a preset period of time. Another option is changing nozzle size to match flow rates to set times. Operation of center pivot, linear move, and solid set systems, by contrast, is flexible in both amount of water applied per irrigation and the interval between irrigations.

The relationship between overall pumping plant efficiency and energy consumption is shown in figure 3. It requires approximately 1.5 kilowatt hours per acre-foot of water per foot of lift when the overall efficiency is 70%. This increases to 2 kilowatt hours at 52.5% efficiency.

Realizing efficiency benefits

Improving pumping plant efficiencies will not necessarily reduce total energy used unless management practices are changed to take advantage of the increased efficiencies. When systems with pumps operating considerably below the published pump performance curves are modified to bring them back to manufacturers' specifications, improvements are realized in increased pressure and increased discharge. However, even with increased pump efficiency, the power requirement may be higher. If the irrigator is currently experiencing underirrigation during peak water-use periods, the increased flow rate will be a major benefit in the form of increased crop yields. On the other hand, if adequate water is being applied prior to the modification, a benefit will result only if the system's operating time is reduced by modifying the irrigation schedule. Failure to so do will result in overirrigating, which wastes water and causes runoff, soil erosion, loss of plant nutrients, and increased energy consumption.

Irrigation scheduling based on crop water needs can help reduce the potential to apply excess water with the higher flow rates. The opportunities for saving energy under those conditions depend on making adjustments in current scheduling programs. More precise scheduling is particularly important in the spring and fall when rain may supplement irrigation. Irrigators tend to apply more water than the plants require during these periods.

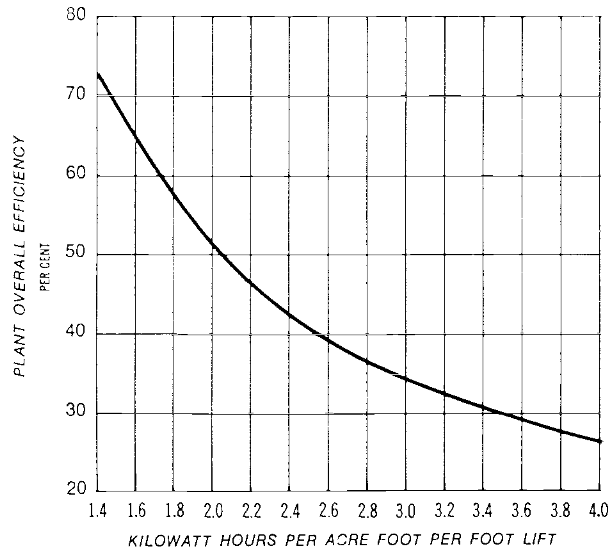

Figure 3.—Relationship between overall pumping plant efficiency and energy required to operate system.

Prepared originally for the Bonneville Power Administration by Hugh J. Hansen, Extension agricultural engineer, and Walter L. Trimmer, Extension irrigation specialist, Oregon State University.

Published and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914, by the Oregon State University Extension Service, O. E. Smith, director; Washington State University Cooperative Extension, J. O. Young, director; the University of Idaho Cooperative Extension Service, H. R. Guenthner, director; and the U.S. Department of Agriculture cooperating. These participating Extension Services are equal opportunity employers, and they offer educational programs, activities, and materials equally to all people. 25/0/25