PUMPING PLANTS AND PUMPING PLANT EFFICIENCY: BASICS WORTH REMEMBERING

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INTRODUCTION

Water well design, construction, and development were discussed in the previous (fifth) issue of this informational series on groundwater, water wells, and pumping plants. This sixth and final issue reviews information on pumping plants and efficiency that when understood can help reduce groundwater pumping costs. An efficient and wisely operated pumping plant can avoid unnecessary energy costs on the order of $500 to $3,000 per year, depending on the size of the pump and extent of operation. If an efficient pump is selected and installed from the beginning and maintained, the cumulative savings over many years can be substantial.

WHAT IS A PUMPING PLANT?

A pumping plant is an energy converter. First, it converts electricity or fossil fuels to mechanical energy and then the mechanical energy to fluid energy moving water at a specific flow and pressure. How efficiently the pumping plant converts electricity or fuels to fluid energy influences the cost of pumping water.

A pumping plant consists of a motor or an engine connected to a pump housing by a drive shaft. Figure 1 shows a motor driven, turbine pumping plant, a common choice for extracting groundwater. There are other pumping plant designs besides turbines such as submersible, centrifugal, and axial flow pumps. The pump housing or bowl contains one or more impellers, called stages. The type and design of pump impeller influences how efficiently the mechanical energy is converted to water flow and pressure. This is referred to as the "bowl efficiency". Semi-open or enclosed impellers are used in turbine and submersible pumps, enclosed impellers are used in centrifugal pumps, and open impellers are used in axial flow pumps. Every pumping plant also has a water intake and discharge point.

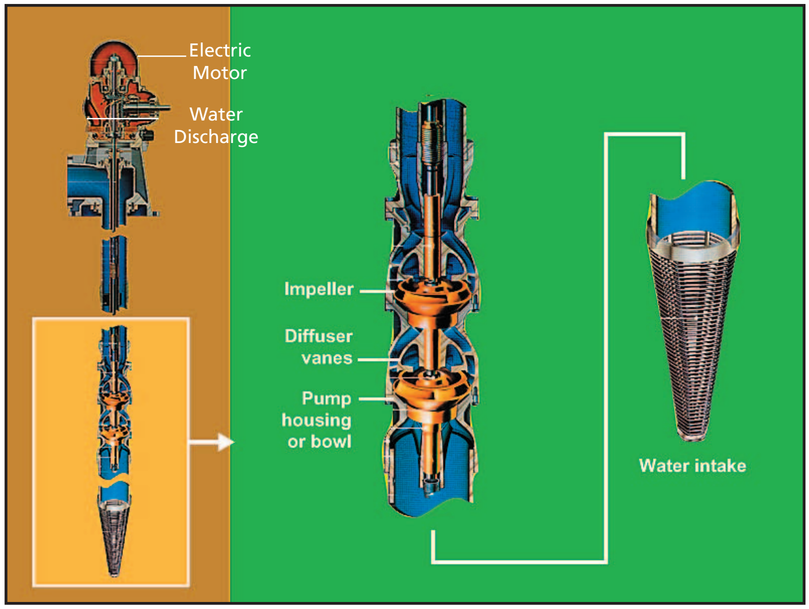

Figure 1. Primary components of a turbine pump and other types of pumping plants: water discharge point and electric motor or alternatively an engine (upper left), shaft connecting motor to pump housing (left center), pump housing containing two stages of impellers (center), and water intake point (far right).

BASIC ENERGY AND COST SAVING CONCEPTS

Horsepower provided by a motor or engine is required to extract groundwater from an aquifer. Another unit that equates to horsepower is kilowatt. One kilowatt equals 1.34 horsepower. Besides horsepower or kilowatts, the time the pump is in operation also influences energy costs. So, electricity used by motor driven pumps is measured in kilowatt-hours and the consumer pays a unit energy cost charged as dollars per kilowatt-hour. Fossil fuel energy used by engine driven pumps is measured in gallons of fuel used per hour and the hours of operation. Figure 2 outlines three basic ways to reduce electricity or fuel costs. This pamphlet primarily focuses on ways to reduce horsepower or kilowatts.

KEYS TO REDUCING PUMPING COSTS

- Reduce Horsepower
- Reduce Operating Hours
- Reduce Unit Energy Cost

Figure 2. Three basic ways to reduce energy costs for pumping groundwater.

REDUCING HORSEPOWER REQUIREMENT

Minimizing the horsepower required by a pump is the first step to reducing energy. This means selecting a pump that is expected to perform efficiently for a specific irrigation system and in specific groundwater conditions. The second step is maintaining that high level of efficiency.

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Selecting an Efficient Pump

Pumps perform differently over a range of conditions primarily due to specific features of the impellers inside the pump housing. Pump manufacturers acknowledge this and publish **pump performance curves.** Pump curves typically provide three important performance relationships in one graphic display: 1) the relationship between pump capacity (gpm) and total head (capacity to lift and pressurize water expressed in feet); 2) the relationship between pump capacity (gpm) and bowl efficiency (%); and 3) the relationship between pump capacity and brake (shaft) horsepower. Curves for different impeller diameters may also be presented in the same graphic.

A properly selected pump based upon comparisons of pump performance curves will:

- Provide enough total head to lift groundwater from an aquifer and to pressurize an irrigation system
- Deliver sufficient flow capacity (gpm) for an irrigation system
- Operate efficiently over a range of expected groundwater conditions
- Operate at a high bowl efficiency
- Operate at a low brake horsepower

Figure 3 provides an example pump performance curve and the dashed box denotes the range of conditions where this pump can be expected to perform efficiently. Depending upon the impeller diameter or sometimes called "trim" (8, 8.5, or 9 inches), it is expected to perform most efficiently (80 to 83 percent bowl efficiency) over a range of flows from 800 to 1150 gpm and a range in total head from 45 to 75 feet. The brake (shaft) horsepower for a single stage impeller ranges from about 12 to 16 hp for these operating conditions. The bowl efficiency of this pump can be expected to decline if operated in conditions outside these parameters or as it wears.

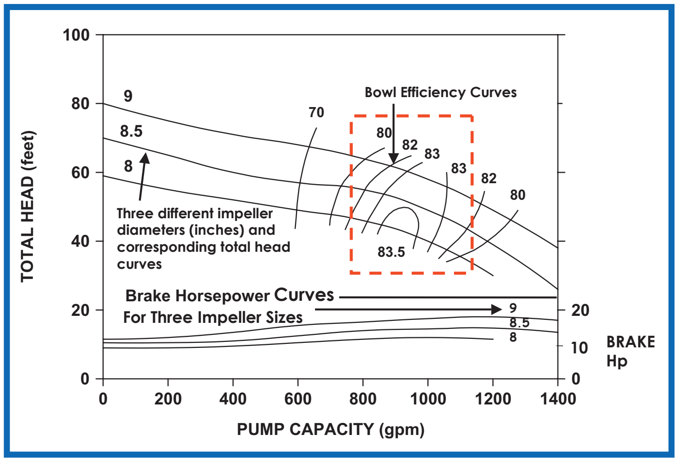


Figure 3. Example pump performance curve for a specific pump.

An operator of a pumping plant should keep a copy of the pump curve for their specific pump. As illustrated in the next section, pump curves can be very useful in troubleshooting a pumping plant that is operating inefficiently. Professional pump distributors or manufacturers can provide and also explain pump performance curves.

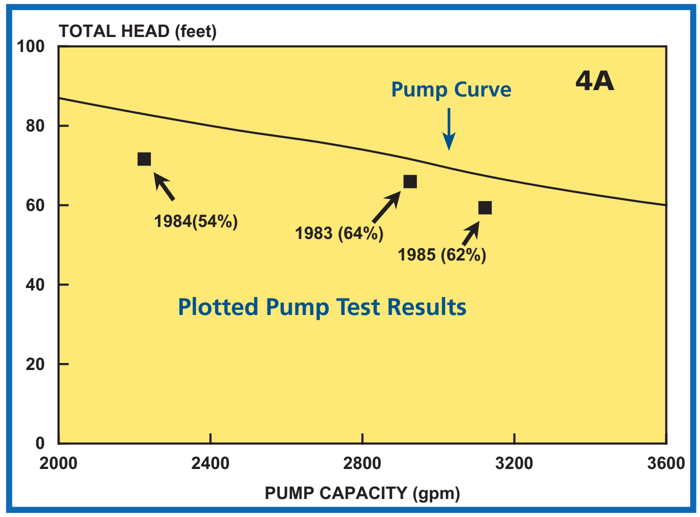
Testing a Pumping Plant for Efficiency

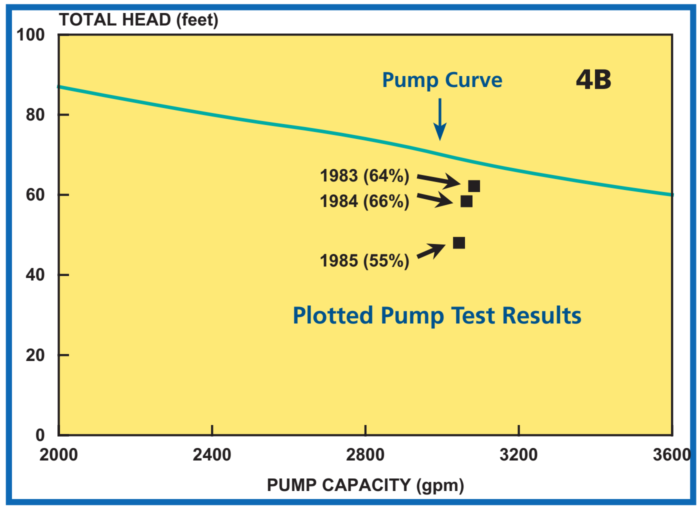
Pump testing is an on-site evaluation of the pumping plant performance while the pump is in operation. It consists of measuring total head, pump capacity, and input horsepower to the pump and then calculating **overall pumping plant efficiency**, the combined efficiency of the pump and motor or engine. A pump test requires access inside the well casing to measure the groundwater level, an accurate measure of flow, and an accurate measurement of irrigation system water pressure. The overall pumping plant efficiency from a pump test will be less than the bowl efficiency in a manufacturer's pump performance curve because the efficiency of the motor or engine is included in the pump test. Pump tests are primarily available through pump dealers. Rebate programs are often available to cover a significant portion of the cost for testing. Pumping plant efficiency above 60 % generally suggests no corrective action is necessary, 50 to 60 % suggests a corrective action may be necessary, and an efficiency less than 50 % indicates a corrective action is needed. However, there are exceptions to these general guidelines as discussed in the next section.

Maintaining an Efficient Pumping Plant

Pump wear, primarily abrasive wear of the impellers, can lead to an inefficient pumping plant. However, modifications to the irrigation system, changes in groundwater levels, or changes in well efficiency can also lead to declining pumping plant efficiency. Figures 4A and 4B illustrate the use of pump test results and pump performance curves to be certain that a corrective action is appropriate. The vertical axis is total head (feet) and the horizontal axis is pump capacity (gpm). The line on each graph represents the manufacturer's pump performance curve and the plotted points (with year and percent pumping plant efficiency) represent three different years of pump test results for two different pumps.

In Figure A, the difference between measured head from pump testing and that from the pump performance curve was relatively constant, although the pump efficiency ranged from 54 to 64 percent. This suggests that the lower pump efficiency measured in 1984 was consistent with pump performance curves and that the pump was operating as expected. The lower efficiency was caused by a change in operating condition, either a decline in groundwater level requiring more pump lift, a change in the irrigation system that required added water pressure, or a change in well efficiency. A corrective action to the pump was not warranted in this situation. The pump returned to a highly efficient level of operation in 1985 without repair, showing the cause of the lower efficiency in 1984 was temporary and not related to pump wear. In Figure B, the difference between measured head from pump testing and that from the pump performance curve declined steadily over three consecutive years confirming pump wear and that an adjustment or repair was needed.





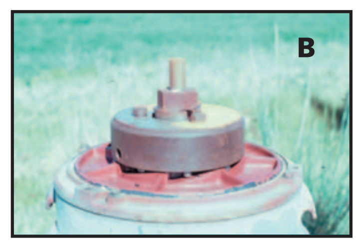
Figures 4A and B. Relationship between total head measured by pump testing compared to total head from pump performance curves for a properly operating pump (A); and for a pump that is not operating properly and in need of repair (B)

Higher Pump Efficiency, Lower Energy Costs?

Three corrective actions may be considered for a pump that is performing inefficiently: 1) an impeller adjustment; 2) pump repair; or 3) pump replacement. An impeller adjustment is usually the first and least expensive (about $200) corrective step to improve pump efficiency. Figures 5a, b, and c illustrate key aspects of an impeller adjustment.

Wear can reduce the pump efficiency by increasing the clearance between the impeller and pump housing. Wear also damages the surface and shape of the impeller. Adjusting, narrowing the clearance between the impeller and the pump housing, can partially restore the pump capacity and total head of a pump when semi-open impellers are used. If an impeller adjustment fails to improve pump efficiency, it is an indicator that either replacing the impellers or replacing the pump is necessary.

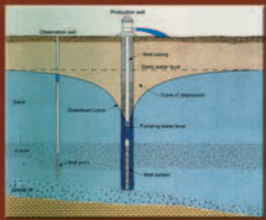
Pump test data following an impeller adjustment show that an adjustment usually results in higher pump capacity (gpm) and pump efficiency but… **input horsepower increases** … so adjusting the impeller will not reduce energy costs unless the pump operating time is reduced sufficiently to compensate for the higher horsepower..



Figures 5A) a worn semi-open impeller; **5 B)** the pump shaft to which the impeller(s) is attached can be adjusted by turning the nut at top of the gear head; and **5C)** sheared impeller resulting from an improper adjustment. ***An adjustment should only be done by a trained professional.***

ADDITIONAL INFORMATION

- Irrigation Pumping Plants. Blaine Hanson. 1994. University of California Irrigation Program. Davis, CA. Available by calling 1- 800-994-8849 or e-mail: **anrpubs@ucdavis.edu**.
- Agricultural Pump Efficiency Program. 2004. Center for Irrigation Technology. California State University. More information available a **www.pumpefficiency.org** or by calling 1-800-845-6038.



This newsletter is the sixth and final in a series discussing topics related to groundwater, water wells and pumping plants.

Pumping Plants and Pumping Plant Efficiency: Basics Worth Remembering

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