EVALUATION OF PUMPING SYSTEMS FOR MAXIMUM EFFICIENCY

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The subjects of energy and water seem to be attracting much attention, particularly so in agriculture. Due to the drought, surface water supplies have decreased, and as a result, many growers are now using groundwater to help meet their irrigation water demands. However, increased groundwater use has also resulted in increased energy use for pumping at a time when the supply of energy is limited. This increase in demand for energy coupled with limited energy supplies means that growers using groundwater need to operate pumping plants as efficiently as possible. Evaluation of the operation of a pumping plant will help determine its efficiency.

Evaluation of Proposed Pumping Plants.

Deep well turbine pumps are able to operate over a wide range of head-discharge conditions. However, good pump efficiencies may be experienced only over a limited range of conditions. If the pump is not operating within that range, its efficiency will be low. Therefore, the operating requirements of a proposed pumping plant must be determined in order to select a pump for efficient performance. These operating requirements include the design discharge and the design total dynamic head.

The design discharge is that desired to meet irrigation requirements and may be estimated from present irrigation practices. However, the design discharge must not exceed the well yield. An initial determination of the feasibility of obtaining the design discharge might be made from discharge data on neighboring wells, but only by testing the well can one be certain of obtaining a particular discharge.

The total dynamic head (TDH) is the sum of the static pumping lift (height of the pump outlet above the drawndown water level), pressure requirements for sprinkler systems or other pressurized systems, velocity head and head losses due to friction. If the pump is located on the ground surface, the static pumping lift is replaced with the static suction lift.

In order to estimate the static pumping lift, the relationship between the discharge and the drawdown must be known. The best information on this relationship is obtained by pumping the well at at least three different discharges during development and testing. The well should be pumped at each discharge until the water-level decline becomes small. Measurements of the drawdown at the well and discharge taken during the test can then be used to develop a characteristic drawdown- discharge curve (Figure 1) for the well. The drawdown caused by the design discharge can now be found from this curve. The sum of the drawdown plus the distance from the pump outlet to the original water level (water level prior to pumping) is the static pumping lift.

Sometimes due to time and monetary limitations, the well may be tested at only one discharge. For this case, the well should be pumped at about the design discharge. The test should be conducted for at least 24 hours or until the water level decline is small. From the drawdown and discharge measurements obtained during this test, the specific capacity of the well can be calculated from

$$\text{Specific capacity} = \frac{Q}{s}, \qquad 1$$

Q= discharge (gpm),

s= drawdown (ft.)

This value can be used to estimate drawdown at a particular discharge provided that the discharge is of the same order of magnitude as the test discharge. If it is not, significant errors in the drawdown estimate may occur.

If drawdown-discharge data on the well are not available, a rough estimate of the specific capacity may be possible by determining this value for neighboring wells. However, much caution should be used for this method. Factors such as varibility of aquifer geology, recharge from streams or other sources, or impermeable boundaries may cause significant differences in specific capacity to exist among wells in the same locality.

The velocity head can be calculated from

$$h = \frac{V^2}{2g}$$

where $$V = \frac{0.408\ Q}{D^2}$$

h= velocity head (feet)
V= velocity of water in pipe (feet per second)
Q= discharge (gpm)
D= internal diameter of pipe (in)
g= 32.2 f/sec^2

The velocity head in most cases will be small and can be neglected in the selection of irrigation wells. For example, if Q= 1400 gpm and the pipe diameter is eight inches, the velocity head is about 2.5 feet. This value will probably be insignificant compared to the static pumping lift.

Friction losses in the column pipe, valves pump head, and fittings may also need to be included in the total dynamic head. Normally, losses in values and fittings can be neglected for small velocity heads. If it is desirable to include them, values for these losses can be found in pump catalogs. A rough estimate of friction losses in a column pipe is about five feet of head per 100 feet of pipe.

When the design discharge and the design total dynamic head have been estimated, a pump that will operate at a high efficiency can be selected using pump characteristic curves contained in pump catalogs. These curves (Figure 2) describe the performance of a pump by a head-discharge curve, an efficiency-discharge curve, and a horsepower- discharge curve. For example, consider the following data.

Depth of the well= 300 feet,
Design discharge = 1400 gpm
Static pumping lift= 95 feet

If the velocity head is neglected then the TDH is the sum of the static pumping lift and friction losses in the column pipe or TDH= 95 feet + 300 feet x 5 feet/100 ft= 110 feet. The curves in Figure 2 indicate that at 1400 gpm, one stage of this pump will produce 54 feet of TDH at an efficiency of 84 percent. Therefore, two stages should meet the design requirements.

The selection process should also consider the possibility that the actual operating conditions may vary from the design conditions due to fluctuating water levels or discharge requirements. The characteristic curves can be used to select a pump that will operate efficiently over a range of head and discharges. From Figure 2, it can be seen that this particular pump will operate at an efficiency of at least 80 percent over a head range of 45-68 feet per pump stage and a discharge range of 1000-1600 gpm. However, if the head- discharge curve were relatively flat (Figure 2a) at the point of the design conditions, a small change in the water level may cause a very large change in the discharge. This may not be desirable.

Once the pump is selected, then the brake- horsepower requirement can be found from the characteristic curve. This, in turn, can be used to select a properly-sized motor or engine.

The overall efficiency of a pumping plant (includes both pump and motor/ engine efficiencies) should be 60-70 percent for electric plants and 15-20 percent for natural gas plants. Although data on gasoline and diesel plants is limited at this time, it is believed that the overall efficiency of these plants is similar to that of natural gas plants. The overall efficiency can be calculated from

$$E_o \text{[1/]} = E_m \times E_p, \qquad 2$$

E_o = overall efficiency,

E_m = efficiency of motor or engine (about 90 percent for electric motors and about 20-25 percent for well- maintained natural gas engines).

Evaluation of Existing Pumping Plants

Causes of low efficiencies in existing pumping plants include an improperly-selected pump, changes in water level, changes in discharge requirements, and pump wear. By conducting pumping tests and comparing the data with the pump characteristic curves, reasons for a low efficiency may be determined. This is illustrated by the example in the next paragraph.

Suppose after five years of operating the pump described by the characteristic curves in Figure 2, a pump efficiency test was conducted. During this five year period the water level declined by 30 feet. Data from the test revealed a plant efficiency of 50 percent, a discharge of 600 gpm, and a total dynamic head of 140 feet. Using equation 2 and an electric motor efficiency of 90 percent, the pump efficiency is calculated to be about 56 percent. However, according to Figure 2, for a TDH of 140 feet or 70 feet per pump stage, the discharge should be 900 gpm and the efficiency should be 76 percent. Therefore, the low plant efficiency may be due to a pump problem such as wear. Correction of the problem may only require an impeller adjustment.

However, suppose an efficiency test revealed a plant efficiency of 50 percent, a discharge of 500 gpm and a total dynamic head of about 156 feet. Again using equation 2 a pump efficiency of 56 percent is calculated. But in this case, the characteristic curves indicate that pump is performing properly since at a TDH of 156 feet or 78 feet per stage and a discharge of 500 gpm, the efficiency of the pump should be about 53 percent. The cause of this low efficiency is probably a decreasing water level. Correction of this low efficiency may require a different impeller design or perhaps a new pump.

In some cases, information on pump characteristics may not be available. Nevertheless, by periodically conducting pumping plant tests and analyzing the data from these tests, information on possible problems may be obtained. This is illustrated by the following:

Table 1 consists of about five years of pumping plant efficiency data of a particular pump. This data is also illustrated in Figure 3. An analysis of this data shows that the efficiency of the pumping plant was good between 1972 and 1977 even though the water level declined about 28 feet over this period. However, a pumping test performed in August of this year revealed an efficiency of 53 percent. Since the water level dropped only about four feet during the past year, pump wear may be the cause of the low efficiency instead of changing water levels. A subsequent test conducted after the pump impeller was adjusted revealed an efficiency of 71 percent and a significantly increased discharge.

TABLE 1. Pumping Plant Efficiency Data.

Date	Total Lift (ft.)	Discharge (gpm)	Kilowatt Hrs. per acre-feet of water pumped	Overall Plant Efficiency
2/18/72	123.5	1000	192	65.5
8/28/73	137.8	940	227	61.5
9/12/75	138.2	800	232	60.5
9/20/76	145.1	695	244	60.0
8/26/77	148.0	605	280	53.5
10/6/77	152.3	910	218	71.0

(Data was obtained from the Pacific Gas and Electric Company)

The benefits this operator can receive by testing his pumping plants and analyzing the test data may be substantial. Suppose this pump was used to irrigate 50 acres of alfalfa, which would require about 4.9 ft. of water per year (including a 15 percent leaching fraction). The total volume of water required is about 250 acre-feet. Prior to the adjustment, 2207 hours were required to irrigate this farm at a power cost of $3406.61. After the adjustment, the increased pump performance enabled the 50 acres to be irrigated in 1462 hours at a power cost of $2772.89. (These figures are contained in Table 2). The time savings was 31 days and the monetary savings was $633.72. The pump adjustment cost about $20. Savings in energy was 15,500 kilowatt hours.

TABLE 2. Pumping Time and Cost Before and After Adjustment.

	Q (gpm)	Yearly Pumping Time (hr)	Cost
Before	605	2207	$3406.61
After	910	1462	$2772.89
Savings		745	$ 633.72

(Costs were calculated using the most recent Pacific Gas and Electric rates.)

The solution to a low pumping plant efficiency may not be as simple as the one in this example. Solving some problems may require extensive repair work or even a new pump or motor. But, if the necessary repairs or adjustments are not made on a poorly performing plant, the situation will probably become worse, thus costing the operator more time and money. Evaluation of a pumping plant will provide information to a operator upon which to base any necessary corrective action.

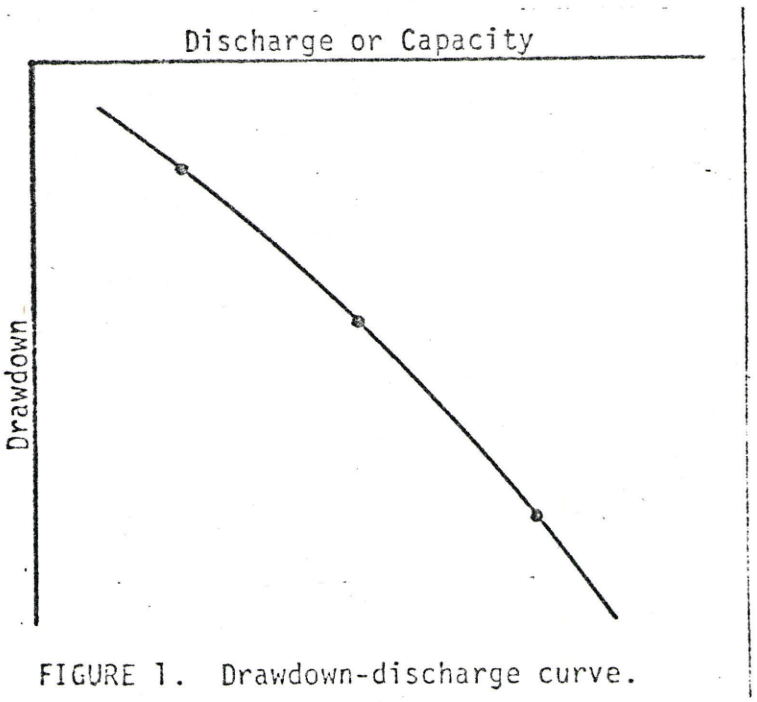


FIGURE 1. Drawdown-discharge curve.

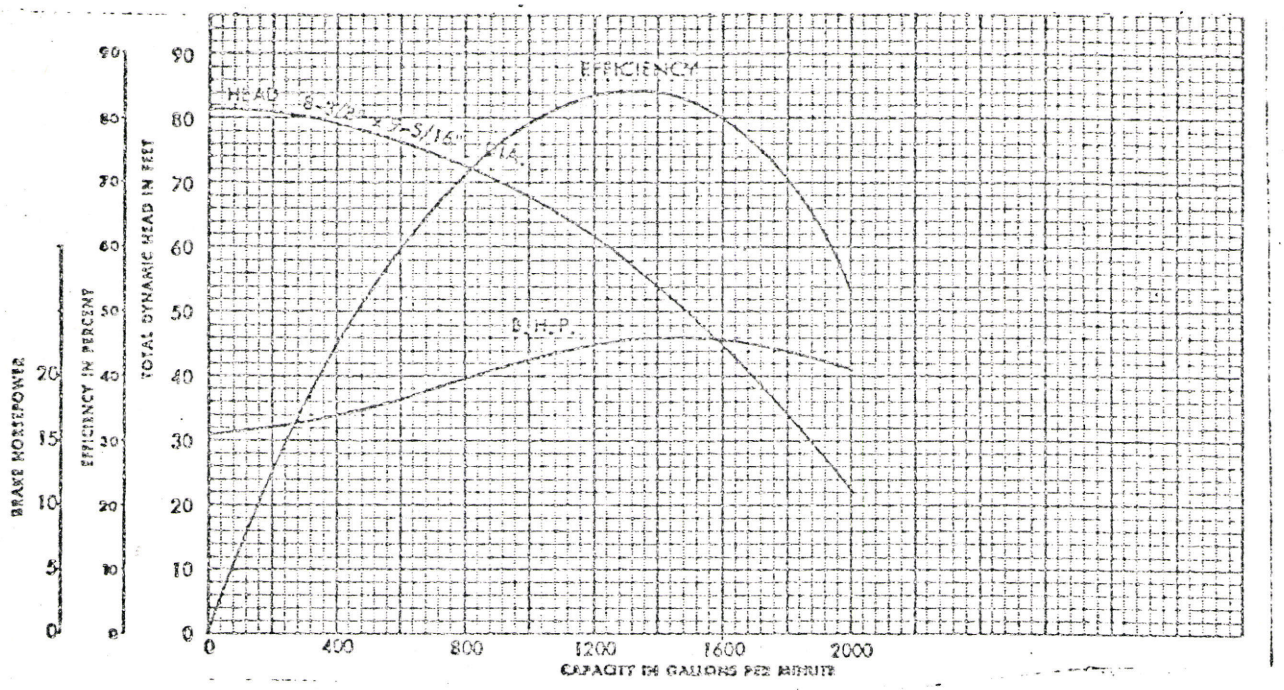


FIGURE 2. Pump characteristic curves (from Berkeley Pump Company catalog).

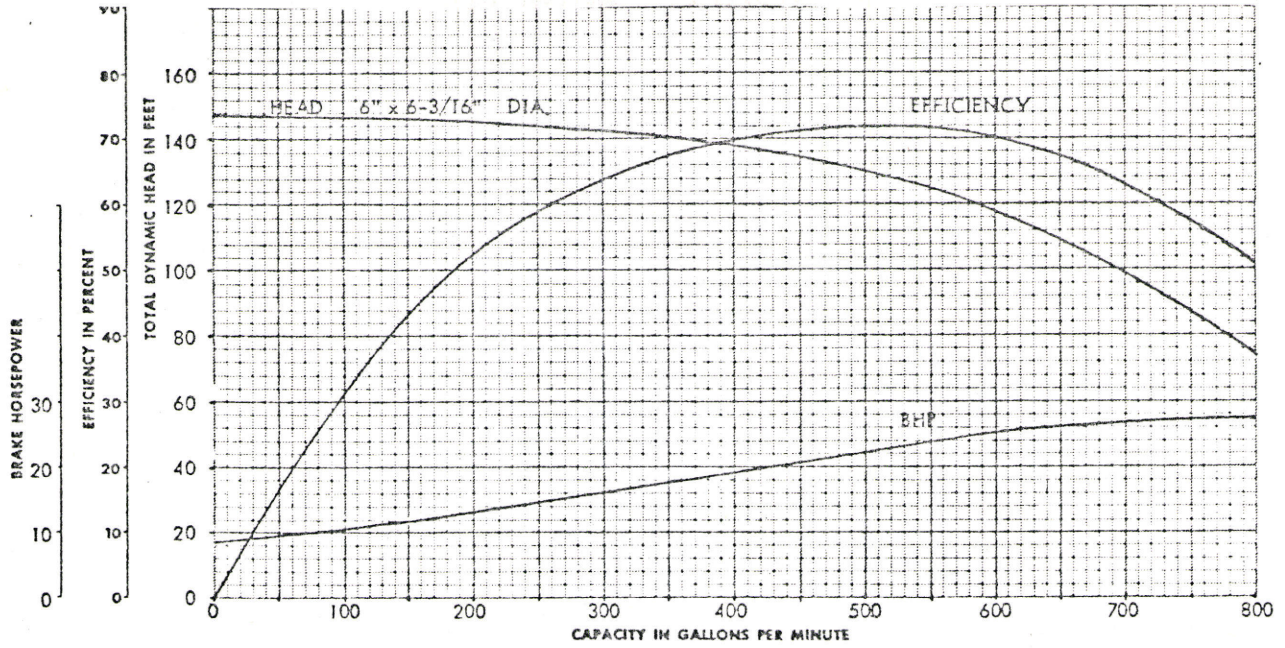


FIGURE 2a. Pump characteristic curves (from Berkeley Pump Company catalog).

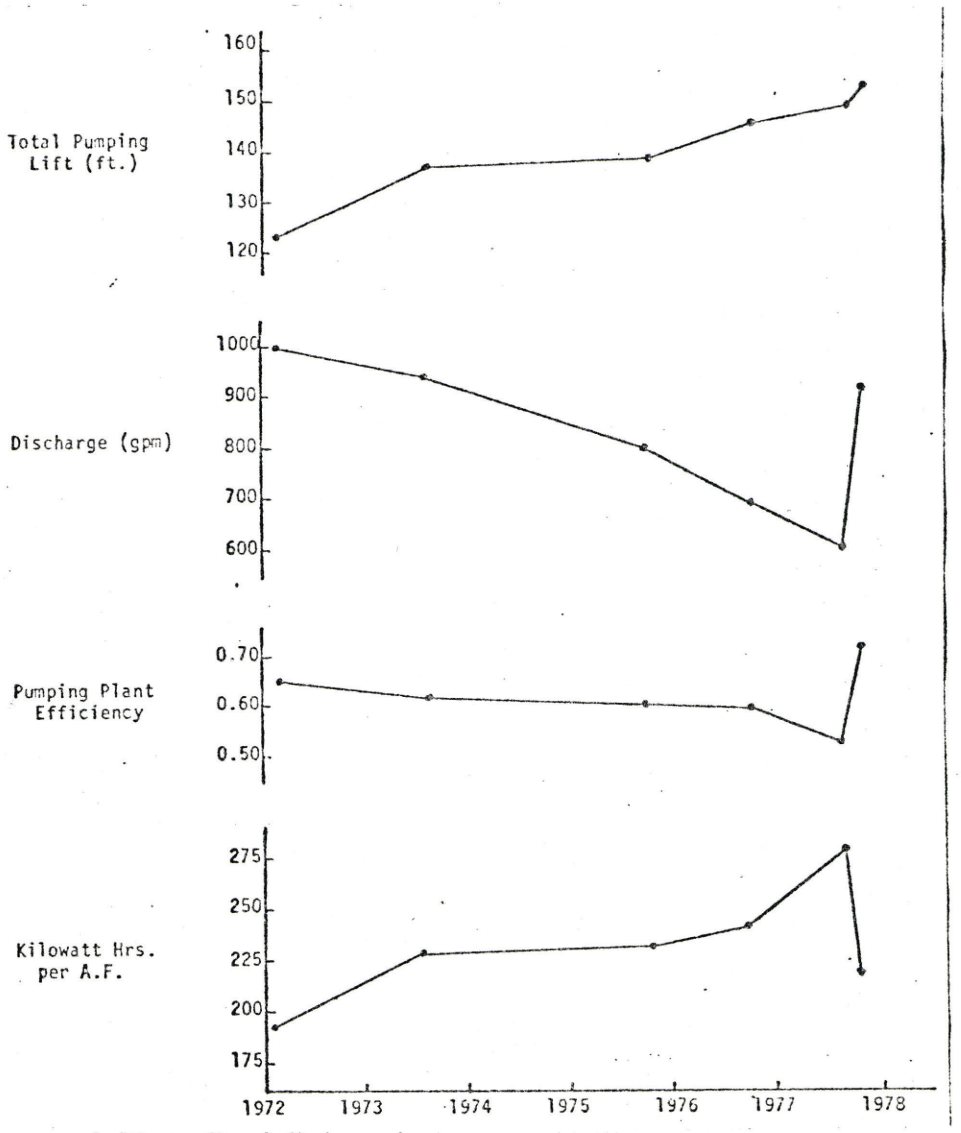


FIGURE 3. Pump Test Data.