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. Therefore, 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 may 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 head.

The design discharge is the discharge desired to meet irrigation requirements. It may be estimated from present irrigation practices, evapotranspiration demand and leaching requirements.

The total dynamic head is the sum of the static pumping lift (height of the pump outlet above the drawn-down water-level), any pressure requirements for sprinkler systems or other pressurized systems, and friction losses in the column pipe, any irrigation system pipelines, pump head, etc. For the case of the pump located above the water level, the static pumping lift is replaced with the static suction lift.

The determination of the static pumping lift requires knowledge of the effect of pumping at the design discharge on the drawdown of the water level. This information should be determined by the well driller during development and testing of the well. The well should be pumped at at least three different discharges for a sufficient period of time at each discharge until the rate of decline of the water level becomes small. The maximum test discharge should be at least 25 percent greater than the design discharge Measurements of the drawdown and discharge taken during the test can then be used to develop a drawdown-discharge curve (Figure 1) for the well. The drawdown caused by the design discharge (and any other desired discharge) can now be found from this curve.

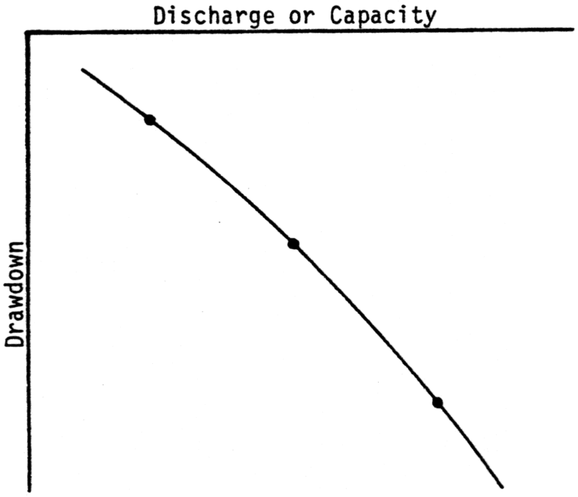

FIGURE 1. Drawdown-discharge curve.

In some cases due to time limitations, the well may be tested at only one discharge. This discharge should be at least 25 percent greater than the design discharge. From the discharge and drawdown measurements of this test, the ratio of the discharge over the drawdown, defined as the specific capacity, can be calculated. Well hydraulics theory states that the specific capacity should be constant for a given well, and thus the drawdown at any discharge can be determined using the specific capacity. In practice, however, well losses may cause the specific capacity to decrease as the discharge increases If high discharge conditions are used to calculate the specific capacity, errors in estimating drawdowns at smaller discharges may result. However, if the well is properly designed for a high efficiency, these errors may be small and a satisfactory value for the drawdown may be obtained.

Friction losses in the column, suction pipe, pump head, etc. should also be included in the total dynamic head. Information on these losses can be obtained from pump manufacturer catalogs.

When the design discharge and the design total dynamic head have been estimated, a pump should be selected using pump characteristic curves published by pump manufacturers (Figure 2). These characteristic curves describe the performance of a pump by a head-discharge curve, an efficiency-discharge curve, and a horse-power-discharge curve. Using these curves, a pump can be selected that will operate at the maximum efficiency under the design conditions.

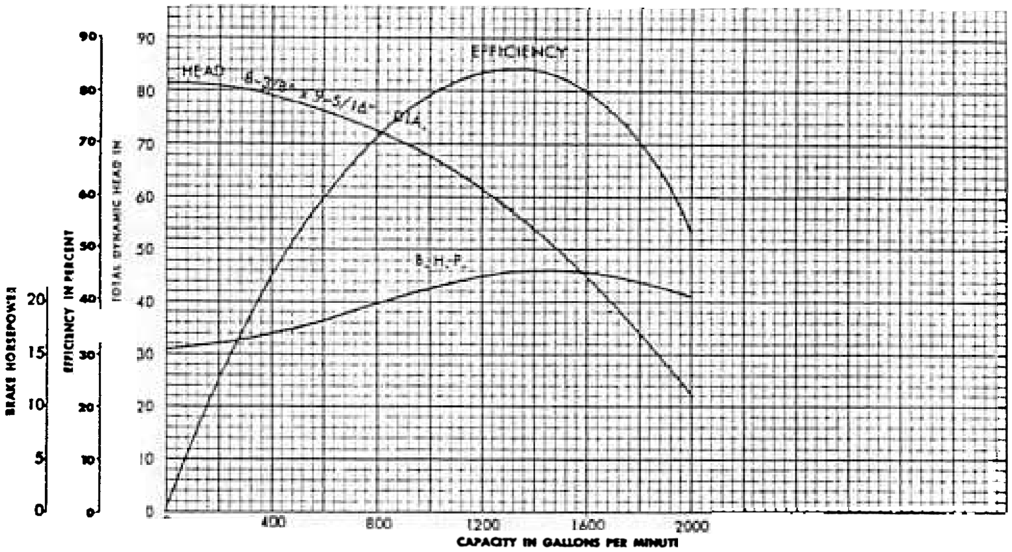

FIGURE 2 Pump characteristic curves (from Berkeley Pump Company catalog)

The selection process should also consider the possibility that the actual operating conditions may vary from the design conditions due to fluctuating water levels, changing discharge requirements, etc. The pump characteristic curves can be used to select a pump that will operate most efficiently over the range of head and/or 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 and a discharge range of 1000-1600 gpm.

After selecting a pump, the horsepower required to drive the pump can be calculated from

$$BHP = \frac{H \times Q}{3960 \times Ep} .$$

BHP= brake horsepower

H= total dynamic head (feet of water)

Q= discharge (gpm)

Ep= pump efficiency

This information can then be used to select a properly-sized motor or engine. The overall efficiency of the pumping plant can then be calculated from-

$$Eo^{1/} = Em \times Ep$$

Eo= overall efficiency

Em= efficiency of motor or engine

The overall efficiency should be about 60-70 percent for electric plants and about 15-20 percent for natural gas plants[2]. Efficiency data on diesel and gasoline powered plants is unavailable at this time, but it is believed that the overall efficiency of these plants should be similar to that of natural gas plants.

Evaluation of Existing Pumping Plants.

Causes of low efficiencies in existing pumping plants that were properly designed for conditions existing at the time of installation include changes in pumping requirements due to water level fluctuations and/or altered irrigation practices, and wear of the pumping system. Although it may be difficult to pin-point a particular cause, a pumping plant test will provide useful data on the performance of a plant. If an operator has regularly conducted these tests, an analysis of the data from these tests may indicate possible problems and future trends. The following example illustrates the benefit of these tests.

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 prior to this year, 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, the low efficiency may be the result of pump wear 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)

1/ The efficiency of any belt drives, gear boxes, etc. to be used in the pumping plant must also be included in the overall efficiency.

2/ Comparing efficiencies of electric and natural gas plants is not valid. The electric plant efficiency does not include the efficiency of the power generating plant and the transmission efficiency. If these are considered, the overall efficiency of an electric plant may be about 20 percent (Pacific Gas and Electric, 1976).

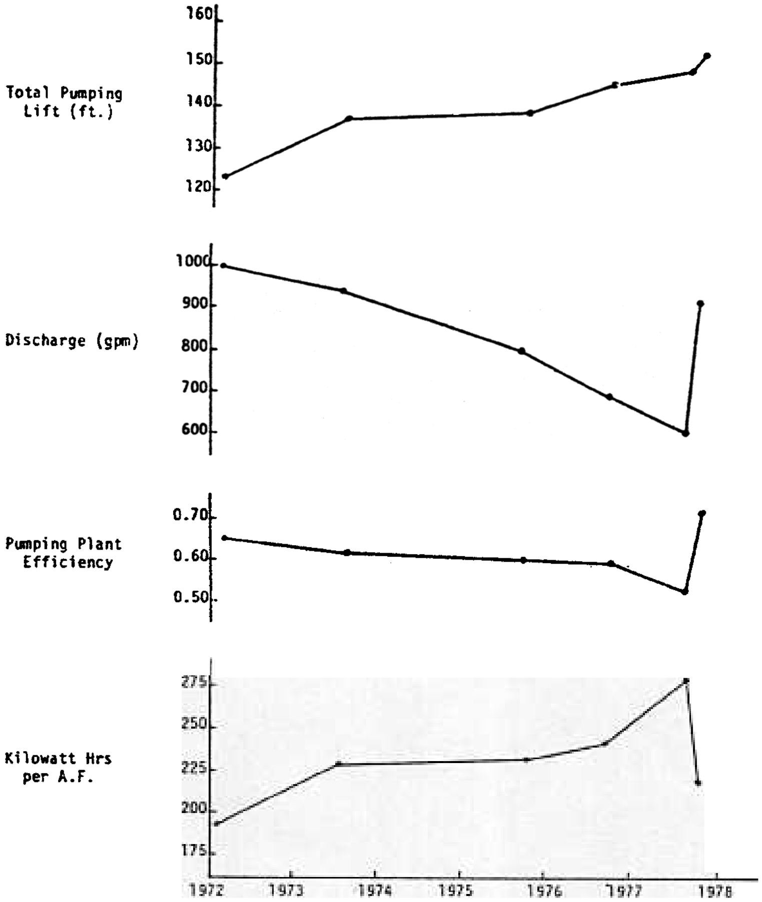

FIGURE 3. Pump Test Data.

The benefits this operator can receive by testing his pumping plants and analysing 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 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 was made, the increased pump performance enable 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.

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.

REFERENCES

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