Operators can evaluate their pumps against design performance to determine irrigation efficiency and pinpoint potential trouble.

Evaluating pumping plant performance

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High energy costs require that irrigation pumping plants be operated as efficiently as possible. Performance must be evaluated periodically so that the pump operator can determine current pump performance; find out if an inefficient pump is operating as designed; and see if pump performance is adequate or what changes are needed to meet irrigation system requirements.

Evaluation should include the following steps:

1. Pump test. This provides data on current performance of the pump by measuring total head developed by the pump, pump discharge, and input power. With these data, overall pumping plant efficiency can be calculated. (The overall efficiency for electric pumping plants includes pump and motor efficiency.)

2. Comparison of pump performance with design performance. Pump performance-characteristic curves developed by the manufacturer describe design performance. These consist of a head-capacity (H-Q) curve, an efficiency-capacity (E-Q) curve, and in some cases a brake horsepower-capacity (BHP-Q) curve (fig. 1, 2, and 4). By comparing head, efficiency, and brake horsepower measured during the pump test with characteristic curves at the measured capacity, one can determine if the pump is operating as designed. This comparison requires information on the pump model, number of stages, and impeller size in addition to test data.

3. Comparison of pump performance with irrigation system requirements. This step shows whether head and capacity developed by the pump are adequate for head and capacity requirements of the irrigation system. An irrigation system head curve can be used to determine the effect of any pumping plant changes on the irrigation system or vice versa. This curve describes the relationship between head and capacity of the irrigation system. It is developed by calculating the total head required by the system for several different capacities and plotting the data as shown in figures 3 and 5. For simplicity, the total head of an irrigation system is the sum of pumping lift, any elevation differences, friction losses, and pressure head. The head-capacity characteristic curve of the pump is superimposed over the system head curve and the intersection of the two is the operating point of the pump.

The following case evaluations illustrate the procedure for evaluating pumping plant performance.

Case I

A pumping plant consisting of a deep-well turbine pump in series with a booster pump was used to irrigate 260 acres with center-pivot sprinklers. The deep-well turbine was a four-stage pump powered by a 100-horsepower motor. A 75-horsepower motor was used for the booster pump. Figures 1 and 2 show the performance characteristic curves of the pumps, and figure 3 the system head curve of the irrigation system.

The pumping plant was tested first with only one center pivot operating and then with both sprinkler systems. Data from the first test (table 1) were used to determine the status of the pumping plant.

Although overall efficiency in the first test was good, that in the second test, which is the normal operating condition, was about 56 percent. The pumping plant was therefore evaluated.

According to the performance curve in figure 1, the booster pump should develop about 215 feet of head at 1,300 gallons per minute (gpm). Comparing this value with that measured shows a difference between the two values of only about 4 percent of the design value, indicating that the booster pump is operating properly. Efficiency of the booster, obtained from the efficiency performance curve, is about 82 percent.

Figure 2 shows that the head developed by one stage of the turbine should be 48 feet, or 192 feet for four stages. The difference between the measured and the design values is nearly 28 percent of the design: Performance

TABLE 1. Results of First Test, Deep-Well Turbine Pump

Characteristics	Data
Capacity of pumping plant	1,300 gpm
Head developed by turbine	138 ft
Head developed by booster	224 ft
Total head	362 ft
Input horsepower*	190
Overall efficiency†	62%

*Input horsepower of both pumps. Power to individual pumps was not measured.
†Overall efficiency = efficiency of motor × efficiency of pump. Pump efficiency can be determined by dividing overall efficiency by the motor efficiency (both expressed as a decimal). Motor efficiency is approximately 90%.

TABLE 2. Test Data for Centrifugal Pump

Characteristics	Data
Discharge	1,400 gpm
Head	166 feet
Input horsepower	87
Brake horsepower	78
Overall efficiency	67%
Pump efficiency	73%

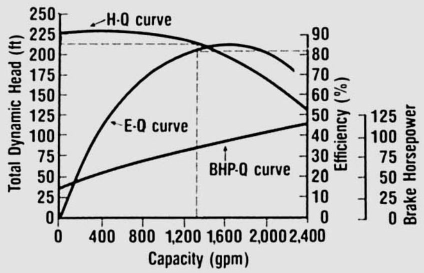

Fig. 1. Booster pump performance curves.

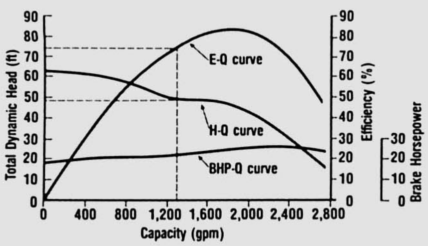

Fig. 2. Pump performance curves for deep-well turbine pump.

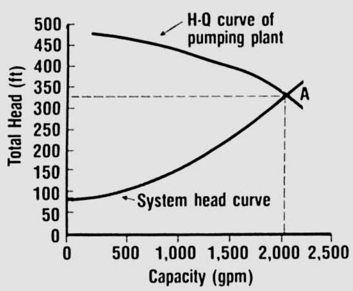

Fig. 3. System head curve of irrigation system; H-Q curve of pumping plant.

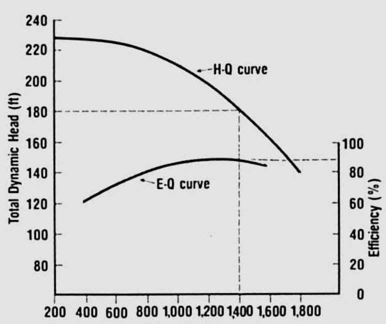

Fig. 4. Centrifugal pump performance.

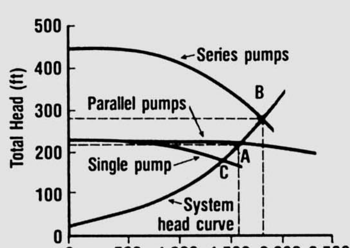

Fig. 5. System head curve and H-Q curves of three pump setups.

of the turbine is below par. Also, the performance curve indicates that pump efficiency should be about 74 percent. Actual efficiency is estimated to be about 55 percent. Thus, the reason for the efficiency measured with both sprinklers operating is believed to be turbine pump performance.

Performance of the pumping plant and the irrigation system for a properly operating turbine can be estimated by superimposing the H-Q of the pumping plant over the system head curve of the irrigation system (fig 3). The H-Q curve of the pumping plant is obtained by summing the heads developed by each pump at a particular discharge for several different discharges.

The two curves intersect at A, where discharge is nearly 2,000 gpm, and the head is about 330 feet. Overall efficiency of the pumping plant under these operating conditions would be nearly 70 percent. (This high efficiency is due primarily to the unusually high efficiency of the booster pump.)

One problem, however, is the horsepower required by the booster. At 2,000 gpm, 105 horsepower (obtained from BHP curve) is required—considerably more than the rated horsepower of the booster motor. Thus, operating at this discharge will require a higher horsepower motor for the booster.

Case II

Another test was conducted on a pumping plant supplying water to seven wheel lines, each of which irrigated about 40 acres (table 2). A centrifugal pump supplied water from a slough.

The H-Q curve (fig. 4) shows that at 1,400 gpm the pump should provide about 180 feet of head. This is about 8 percent greater than that measured, an insignificant difference. Pump plant efficiency is very good.

Although the pump is operating properly, a comparison of the pump performance with the irrigation system requirement shows the pump to be inadequate. At 1,400 gpm, the average flowrate per wheel line is only 200 gpm, which is less than is desirable.

To increase capacity of the pumping plant, the operator considered adding a similar pump either in parallel or in series with the existing pump. A system head curve coupled with the H-Q curve of the pump was used to evaluate the two pumping plant modifications (fig 5). Operating point for the parallel system is at A and at B for the series system. This shows that the series system will develop more pressure and head (Q = 1800 gpm, H = 280 feet) than the parallel system (Q = 1600 gpm, H = 210 feet).

For the parallel system, the total head developed by the pumping plant is the same as that developed by each pump. Thus, since more head is needed to pump more water through the irrigation system, the operating point of each pump must move to the left along the H-Q curve of a single pump (in direction of increasing head), thus decreasing the capacity of each pump. The final result is that each pump would produce only about 800 gpm.

Although the series system develops more head than a single pump, the 140-foot head developed per pump is less than that of the single pump system. Thus, the operating point of each pump on the H-Q characteristic curve moves to the right in the direction of increasing capacity. However, the increase can be costly in energy consumption. By doubling the horsepower requirement of the pumping plant, the capacity was increased by only 30 percent—a change from 18.7 to 12 gpm per horsepower. Although the water supply increased, benefits of any yield increase due to the increased water supply would need to be compared with the additional energy cost to determine if this modification is cost-effective.

Summary

For the first case, evaluation showed that the turbine pump performance was inadequate. Potential output of the pumping plant and its effect on the irrigation system were determined using the system head curve and the pump performance curve. In addition, a potential problem with the motor size of the booster pump was also identified.

In the second case the pump was operating as designed but was inadequate for the irrigation system requirements. Using the system head curve, several alternatives for increasing the water supply were analyzed. Evaluation showed that the pumps-in-parallel alternative was of no value. The pumps-in-series alternative would increase the water supply but would be costly.

By following steps used in these analyses, operators can evaluate performance of their pumps against design performance. The procedure will also help operators identify present and potential problems and thus possibly avoid situations that could adversely affect irrigation of crops.

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