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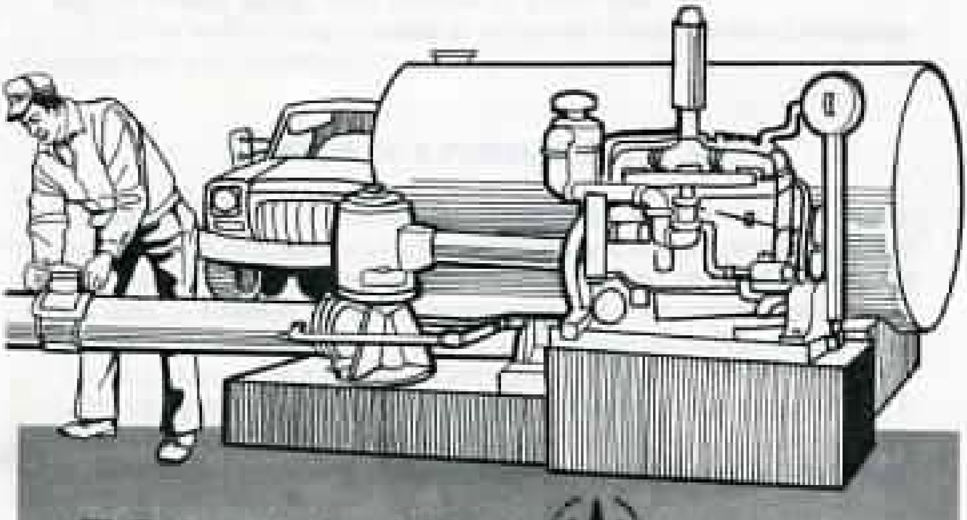

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It Pays to Test Your Irrigation Pumping Plant

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INTRODUCTION

A pumping plant performance test can determine energy efficiency of an irrigation pumping plant and provide information on adjustments needed to improve energy efficiency. Performance of an irrigation pumping plant should be evaluated by trained personnel using accurate testing equipment. This service can be performed by consulting engineers, by many well drilling companies, Natural Resources Districts, and Public Power Districts. See your County Extension Agent for more information concerning these services.

A pumping plant test should be performed regardless of the age of your system. Test all new systems so that you can be assured that your unit meets the contract specifications. Most systems should be at least equal to the Nebraska Performance Criteria for pumping plants (Table 1). The components should be carefully selected, installed, adjusted and operated to obtain these standard values.

For an existing pumping plant a test can determine:

1. If energy and money can be saved by adjusting, rebuilding, or replacing the existing pump, drive systems, or power unit.
2. If the well is being operated at too great a discharge rate for existing pump and well conditions.

BENEFITS OF A PUMPING PLANT TEST

Information obtained during the test includes water levels while pumping, pumping rate, discharge pressure, pump and engine speed, and energy use. Conditions such as pumping sand or air should be noted. These data are used to establish the performance rating of your pumping plant at its present discharge rate. Since you can also operate the unit at several other discharge rates, you may learn more about the following items.

Pumping Rate—From the test you can determine if the pumping rate is satisfactory or if it is possible to expand your irrigated acreage or if the acreage should be reduced. Knowledge of the pumping rate is also essential

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for calculating the amount of water applied and for irrigation water management.

Water Levels—The test can help you determine at which discharge rate your pump should operate. If you are over-pumping your well and are pumping sand or air, the test can help you determine a practical pumping rate. In addition, the test can help you determine if lowering the pump bowls is required for more efficient pump operation.

Discharge Pressure—The test will determine the pump pressure for operating your distribution system. The person performing the test will be able to advise you if this is the design pressure of your distribution system.

Pump and Engine Speed—The test will determine if the pump and power unit are being operated at the most efficient point. These data can also be helpful in determining if the power unit is overloaded or if the power unit and pump are operating at the wrong speeds. The values can indicate to you if a belt drive system has excessive slippage.

Energy Use—Knowledge of your energy use for the work being accomplished will allow you to evaluate your irrigation costs. Cost is the primary reason for the performance test.

EVALUATION OF YOUR PUMPING PLANT

Accurate test measurements are needed to evaluate the performance of a pumping plant. Data used are:

1. Measurements of lift (water level with pump operating), discharge pressure, and discharge rate—used to determine the rate work is being done by the pumping plant.

2. The rate work is done by the pumping plant, divided by the energy use rate of the power unit, establishes the pumping plant level of performance.

3. The measured performance, evaluated against the Nebraska Performance criteria for pumping plants (Table 1), determines how it compares.

If components are carefully selected and if larger power units and pumps with more than one pump bowl are used, it is possible to obtain a pumping plant which will exceed the criteria.

A small pumping plant or reuse system may be less efficient than the criteria. Whenever the published head capacity curves are available, the pump tester should use the curve to determine the actual efficiency that can be expected from the pump.

The following examples illustrate how data are used to obtain the pumping plant performance rating.

Example 1[2]

Field test data — Gated Pipe

Power unit	30 hp electric motor
Pumping rate	700 gallons per minute (gpm)
Lift	75 feet (ft)
Pressure	10 pounds per in^2(psi)
Energy use rate	25 kilowatt-hours per hour (kW h/h)

[2] For an example using metric units see Appendix.

1. *Determine water horsepower (whp)* (rate energy is added to water)

$$\text{whp} = \frac{\text{pumping rate (gpm)} \times \text{total head (ft)}}{3{,}960}$$

Total head (ft) = Lift (ft) + (2.31 x Pressure [psi])

Total head (ft) = 75 + (2.31 x 10) = 98.1 ft

$$\text{whp} = \frac{700 \text{ gpm} \times 98.1 \text{ ft}}{3{,}960}$$

= 17.3 hp

2. *Determine pumping plant performance* (water horsepower divided by rate of energy use)

$$\text{whp divided by kW.h/h} = \frac{17.3 \text{ whp}}{25 \text{ kw·h/h}}$$

= 0.692 whp·h/kw·h

3. *Determine the performance rating*

a. Obtain Nebraska Performance criteria from Table 1.

whp.h/kW.h
= 0.885

b. Performance Rating = $\frac{\text{measured whp·h/kW·h}}{\text{Nebraska Performance criteria}} \times 100$

Performance Rating = $\frac{0.692}{0.885} \times 100$

= 78%

4. *Determine excess energy use per hour of operation*

Excess energy use = $\frac{100 - \text{Rating}}{100} \times$ Measured Fuel Use

$= \frac{100 - 78}{100} \times \frac{25 \text{ kW·H}}{\text{h}} = \frac{5.5 \text{ kW·h}}{\text{h}}$

Example 2

Field test data - Center pivot (or other sprinkler system)

Power unit	125 hp diesel engine
Pumping rate	800 gpm
Lift	100 ft
Pressure	65 psi
Energy use rate	4.9 gallons per hour (gal/h)

1. *Determine water horsepower*

   Total head (ft) = 100 + (2.31 x 65) = 250 ft

   whp = $\frac{800 \text{ gpm} \times 250 \text{ ft}}{3{,}960}$ = 50.5 whp

2. *Determine pumping plant performance*

   = $\frac{50.50 \text{ whp}}{4.9 \text{ gal/h}}$

   = 10.3 whp·h/gal

3. *Determine the performance rating*

   a. Performance criteria (Table 1) = 12.5 whp·h/gal

   b. Rating = $\frac{10.3}{12.5} \times 100$

   = 82%

4. *Determine excess energy use per hour of operation*
Excess energy use/hr

$$= \frac{100 - 82}{100} \times 4.9 \text{ gallon/hr}$$

= 0.86 gallons diesel/h

CAUSES OF BELOW STANDARD PERFORMANCE

Any of the three major pumping plant components—pump, drive, or power unit—can cause poor performance. In addition, mismatching of components, poor selection of components, changing water levels, or changing pressure on the irrigation system may cause reduced efficiency.

The Pump—A pump's impeller(s) is selected to deliver efficiently a particular rate of water to a certain elevation (including pressure head) and at a specific speed. It is possible to select impellers which are quite efficient for a wide range of conditions or to choose an impeller which is even more efficient for only one specific set of conditions. In some cases this more specifically selected impeller will be inefficient when conditions are altered. The addition of pressurized discharge distribution systems or the redesign from a high to low pressure discharge distribution system can cause pump efficiency to decrease. Have technically qualified individuals make the initial impeller selection and help determine if your impellers are matched to existing operation conditions.

Pump impellers can be out of adjustment. Impellers out of adjustment will require greater than normal pump and engine speeds to deliver a specified amount of water. Trained individuals and qualified pump manufacturers' representatives are able to adjust impeller clearances to obtain optimum pump capacity and head. EC 81-760, How to Adjust Vertical Turbine Pumps for Maximum Efficiency,[3/] provides information for adjusting an impeller. Worn or corroded impellers cannot be brought completely back to original capacity, head, or efficiency by adjustment, but sometimes may be improved.

When selecting a pump for a given installation, the designer will choose a pump that will operate efficiently at some rotational speed. Usually this will be the electric motor speed of 1760 rpm. Pumps can operate with equally high efficiencies at other speeds so long as the designer has matched the operating characteristics of the pump at that speed to the conditions. The use of an accurate tachometer will enable the operation of the pump at the design speed.

[3/] Available through your local County Extension Office.

For centrifugal pumps, warping of the pump case or bending of the pump shaft may cause increased friction of the rotating part. The wear ring can allow internal circulation of water in some instances. Improperly designed suction and discharge assemblies can cause reduced efficiency.]

The Power Unit—A power unit can require more fuel than normal if it is not loaded properly, if it lacks proper servicing, if it is not "tuned" properly, or if it contains worn components.

Internal combustion engines work most efficiently when operated between 75% and 100% of their continuous duty rated horsepower and when they are operated at the correct speed. Technically qualified individuals can advise you on the proper selection of drive ratios for new pumping plants so that the engine will be correctly loaded and operate at the correct speed. They can also advise you if an existing system has the correct drive ratio.

Proper maintenance of the power unit is also necessary for efficient operation of a pumping plant. A power unit should be serviced at regular intervals and should be winterized for the off season. In addition, an engine should receive a tune-up as required. For spark ignition systems the tune-up should consist of ignition timing, spark plug and point replacement, and a cleaning and adjustment of the carburetor. For diesels the entire fuel injection system may requie servicing. During the tune-up the air cleaner should be serviced and valve clearance should be adjusted. A tune-up can result in a substantial reduction in fuel consumption.

Excessively worn engine valves and piston components may allow a compression loss resulting in poor fuel economy. Compression tests can be run on the engine to determine which components require replacement or need to be rebuilt. A worn engine will significantly affect the efficiency of a pumping plant.

The efficiency of electric motors seldom change during use for a given load. If the motor is underloaded, it will operate less efficiently than it will under proper load. If the motor is overloaded according to the service factor, efficiency may not be reduced, however, motor life will be shortened.

The Drive—The drive ratio may not be correctly matched between the pump and engine for proper speeds. This causes inefficient operation of the pump, the engine, or both units. Drive misalignment will increase friction and reduce driveline life.

Technically qualified individuals with the manufacturers' pump and engine curves can select the correct drive ratio.

SUMMARY

Recent tests have shown that improved performance of the average pumping plant in Nebraska can save 25% of irrigation fuel costs. The only way to know for sure is to have it tested.

Table 1. Nebraska performance criteria for pumping plants.

Energy source	hp·h[a] Unit of energy	whp·h[b] Unit of energy[c]	Energy units
Diesel	**16.66**	**12.5**	**gallon**
Gasoline	**11.5**[d]	**8.66**	**gallon**
Propane	**9.20**[d]	**6.89**	**gallon**
Natural gas	**82.2**[e]	**61.7**	**1000 ft³**
Electricity	**1.18**[f]	**0.885**[g]	**kW·h**

[a] hp·h (horsepower-hours) is the work being accomplished by the power unit with drive losses considered.

[b] whp·h (water horsepower-hours) is the work being accomplished by the pumping plant at the Nebraska Performance Criteria.

[c] Based on 75% pump efficiency.

[d] Taken from Test D of Nebraska Tractor Test Reports. Drive losses are accounted for in the data. Assumes no cooling fan.

[e] Manufacturers' data corrected for 5 percent gear head drive loss with no cooling fan. Assumes natural gas energy content of 925 BTU per cubic foot. At 1000 BTU per cubic foot energy content use a Performance Criteria of 88.9 hp·h/1000 ft for natural gas.

[f] Assumes 88 percent electric motor efficiency.

[g] Direct connection, assumes no drive loss.

APPENDIX - NECESSARY TABLES, EQUATIONS AND AN EXAMPLE CALCULATION USING METRIC UNITS

Table 1A. Nebraska performance criteria for pumping plants.

Fuel	kW·h[a] Unit of energy	wkW·h[b] Unit of energy[c]	Energy units
Diesel	**3.28**[d]	**2.48**	**liters**
Gasoline	**2.28**[d]	**1.71**	**liters**
Propane	**2.07**[d]	**1.36**	**liters**
Natural gas	**2.17**[e]	**1.63**	**m³**
Electricity	**0.880**[f]	**0.660**[g]	**kW·h**

[a] kW·h (kilowatt-hours) is the work being accomplished by the power losses considered.

[b] wkW·h (water kilowatt-hours) is the work being accomplished by the pumping plant at the Nebraska Performance Criteria.

[c] Based on 75% pump efficiency.

[d] Taken from Test D of Nebraska Tractor Test Reports. Drive losses are accounted for in the data. Assumes no cooling fan.

[e] Manufacturers' data corrected for 5 percent gear head drive loss with no cooling fan. Assumes energy content of 34.5 (megajoules) MJ per cubic meter. At 37.3 MJ per cubic meter use Nebraska Performance Criteria of 2.35 kW·h/m³ of natural gas.

[f] Assumes 88 percent electric motor efficiency.

[g] Direct communication, assumes no drive loss.

Example: (same as Example 1 English Units)

Field test data — Gated Pipe

Power unit ....22.4 kg Rating
Pumping rate ....44.2 liters/second (l/s)
Lift ....22.9 meters (m)
Pressure ....68.9 kilopascals (kPa)
Energy use rate.....................25 kilowatt-hours per hour (kW.h/h)

1. *Determine water kilowatts (wkW)* (rate energy is added to the water)

Total head (m) = Lift (m) + (.102 x pressure [kPa])

Total head (m) = 22.9 + (.102 x 68.9) = 29.9

$$wkW = \frac{44.2 \times 29.9}{102.4} = 12.9 \text{ kW}$$

2. *Determine pumping plant performance* (water kilowatts divided by rate of energy use)

$$wkW \div kW{\cdot}h/h = \frac{12.9 \text{ wkW}}{25 \text{ kW}{\cdot}h} = 0.516 \text{ wkW}{\cdot}h/kW{\cdot}h$$

3. *Determine the performance rating*

(a) Obtain Nebraska Performance criteria from Table 1A. wkW·h/kW·h = 0.660

(b) $$\text{Rating} = \frac{\text{measured wkW·h/kW·h}}{\text{Nebraska Performance Criteria}} = \frac{0.516}{0.660} = 0.78$$

4. *Determine excess energy use per hours of operation*

Excess energy use = (1.00 - Rating) x measured fuel use (1.00 - .78)

$$\frac{25 \text{ kW}{\cdot}h}{h} = 5.50 \frac{\text{kW}{\cdot}h}{h}$$