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EC84-725 Pumping Plant Repair Feasibility

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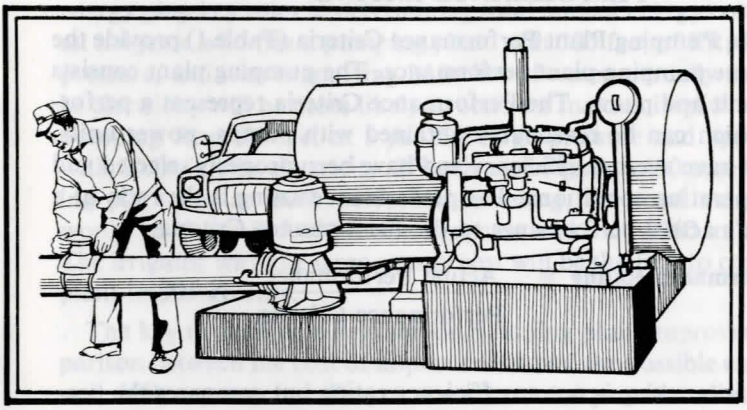
PUMPING PLANT
REPAIR FEASIBILITY



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PUMPING PLANT REPAIR FEASIBILITY

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INTRODUCTION

Energy costs for pumping irrigation water are a major part of the cost of producing irrigated crops. Improvement of pumping plant performance is one way Nebraska irrigators can reduce energy costs. This circular presents a method for determining the economic feasibility of improving pumping plant performance.

PERFORMANCE RATING

The Nebraska Pumping Plant Performance Criteria (Table 1) provide the basis used to rate pumping plant performance. The pumping plant consists of the power unit and pump. The Performance Criteria represent a performance level which can be reasonably obtained with pumps, power units, and drives that have average efficiency and have been properly selected and matched for operating conditions. The performance rating is the ratio of a pumping plant's actual performance to the Performance Criteria.

$$\textbf{Performance Rating} = \frac{\text{Actual Performance}}{\text{Performance Criteria}} \times 100$$

The performance rating is not an efficiency rating but compares the performance of a pumping plant to the Performance Criteria. Actual performance can exceed the Performance Criteria shown in Table 1.

The pumping plant performance rating is determined after measuring pumping rate, pumping lift, discharge pressure, and energy or fuel use under normal operating conditions. These tests can be done by many well drillers or pump installers, irrigation consultants, and some Rural Public Power Districts, Natural Resources Districts, and Soil Conservation Service County offices. An individual irrigator can conduct a simplified pumping plant test using equipment available for loan from County Extension Offices. The simplified test will show the pumping plant's current performance rating, but will not provide all the information necessary to determine causes of poor performance. More information on evaluating pump-

ing plant performance is available in "It Pays to Test Your Irrigation Pumping Plant", Extension Circular 81-713.

The pumping plant performance rating will indicate whether pumping plant improvement should be considered. Pumping plant improvements may include engine or motor maintenance, pump adjustment, drive replacement, pump replacement, and power unit replacement. Energy cost savings will depend on several factors, including:

1. Existing performance rating.
2. Rate of performance rating decline.
3. Total pumping head.
4. Total quantity of water being pumped.
5. Cost of energy.
6. Cost of improving performance.

A high performance rating generally indicates that no improvement is needed. As a "rule of thumb", if the performance rating is 90% or higher, improvements would probably be limited to power unit maintenance and pump adjustment.

The total pumping head, quantity of water being pumped, and cost of energy play key roles in determining total annual energy cost. For example, an irrigator who has a pumping plant with 300 feet of lift, 75 psi discharge pressure, and who is applying 24 inches of water annually using $0.065/kw-hr electricity will be more likely to consider making improvements than one pumping from 20 feet at 5 psi discharge pressure and applying 10 inches with $0.04/kw-hr electricity. If both are irrigating 130 acres and the pumping plant has an 80% performance rating, the total annual energy cost would be about $15,400 in the first case and only $260 in the second case. The irrigator with the large energy cost will be the first to consider pumping plant improvements.

The key to making a decision on pumping plant improvements is a comparison between the cost of improvement and the possible energy savings. A well driller, pump installer, or consultant can provide reliable estimates on possible improvement costs. An estimate of the performance rating after improvement is also necessary. University of Nebraska pumping plant tests throughout Nebraska have indicated that pump adjustment alone can improve the performance rating 5 to 15% when performance ratings were below 100%. Natural gas and propane engine tuneups also provided similar improvement.

After the pumping plant performance rating and the estimated cost of improvement have been found, a decision must be made on whether the investment for improving performance is feasible. Economic feasibility evaluation considers the profitability of a planned investment and can be used to compare alternative investments. Financial feasibility addresses whether the cash flow resulting from an investment will pay the investment costs. A

feasible investment is one in which the cash flow after taxes meets the investment loan (capital) commitment.

An example and work sheet for determining economic feasibility using an amortization technique follows. This technique determines a series of uniform annualized investment costs for depreciation and interest over the analysis period. The investment in making pumping plant performance improvements will be economically feasible if the resulting annual energy savings are equal to or greater than the annualized investment cost of the improvements.

The amortization technique uses a factor, commonly called the capital recovery factor (CRF), to determine the annualized investment cost. The capital recovery factor is given by:

$$\mathbf{CRF} = \frac{i\,(1+i)^n}{(1+i)^n - 1}$$

where: CRF = capital recovery factor
i = interest rate
n = cost recovery period (loan period) or life of investment.

Capital recovery factors are shown in Table 2. The annualized investment cost then is:

Annual Cost = Total Investment Cost (Present Value) x CRF.

This annual cost is the amount that will pay interest and depreciation over the period chosen. The time period used can be the life of equipment or repair; a cost recovery time, or the length of time desired to recover the cost of the investment; or the length of a loan to cover the investment. The interest rate used is not necessarily the interest rate paid on borrowed money since the entire investment may not be made using borrowed capital. Part of the investment could be made with internal financing. The appropriate interest rate is the "cost of capital" and may be one of the following:

1. Interest rate before taxes attainable by placing money on deposit in interest earning accounts in lending institutions as an estimate of the opportunity cost of capital.
2. Interest at "going" rates on borrowed money.
3. A weighted average after tax cost of capital using:
   a. Present cost of borrowed funds from each source.
   b. Average cost of internal capital as estimated by considering percentage of equity in business and risks being taken.
   c. Adjustment for income tax effect.

4. An acceptable minimum rate of return.

The time period and interest rate used will vary with individual situations. After a time period and interest rate are selected, Table 2 will give the capital recovery factor.

The following example illustrates the amortization method of evaluating the economic feasibility of improving pumping plant performance. The example uses data from a pumping plant performance test and calculates the performance rating.

EXAMPLE

Information from Pumping Plant Test

Pumping Rate = 600 GPM

Lift =	165 ft
+	+
Discharge Pressure = 65 psi x 2.31 =	150 ft
Total Pumping Head =	315 ft

Energy Type = Diesel
Energy Use = 5.3 gal/hr
Energy Cost = $1.00/gallon
Acres Irrigated = 130 acres
Water Applied = 8 inches

Calculations

1. Water-horsepower (whp) = $\dfrac{\text{Pumping Rate, GPM} \times \text{Total Pumping Head, ft}}{3960}$

$$\text{whp} = \frac{600 \text{ GPM} \times 315 \text{ ft}}{3960} = 47.7$$

2. Pumping Plant Performance

$$\text{Performance} = \frac{\text{whp}}{\text{energy use or fuel consumption}}$$

$$\text{Performance} = \frac{47.7 \text{ whp}}{5.3 \text{ gal/hr}} = 9.0 \text{ (whp-hr/gal)}$$

3. Performance Rating

$$\text{Rating} = \frac{\text{Actual Performance}}{\text{Performance Criteria (From Table 1)}} \times 100$$

$$\text{Rating} = \frac{9.0 \text{ (whp-hr/gal)}}{12.5 \text{ (whp-hr/gal)}} \times 100 = 72\%$$

4. Total Annual Energy Cost

$$\text{Pumping Rate in ac. in./hr} = \frac{\text{Pumping rate, GPM}}{450 \text{ (GPM/ac. in./hr.)}}$$

$$\text{Pumping Rate} = \frac{600 \text{ GPM}}{450} = 1.33 \text{ (ac. in./hr)}$$

Energy Cost per Acre Inch =

$$\frac{\text{Energy Use, (unit of energy/hr)} \times \text{Energy Cost, (\$/unit of energy)}}{\text{Pumping Rate, (ac. in./hr)}}$$

$$\text{Energy Cost} = \frac{5.3 \text{ (gal/hr)} \times \$1.00/\text{gal}}{1.33 \text{ (ac. in./hr)}} = \$3.99/\text{ac. in.}$$

Total Annual Energy Cost =

$$\text{Acres Irrigated} \times \begin{matrix}\text{Average Total} \\ \text{Irrigation Applied, In.}\end{matrix} \times \text{Energy cost/ac. in.}$$

Total Annual Energy Cost = 130 ac x 8 in x \$3.99/ac. in. = \$4,149.60

5. Potential Annual Savings by Improving Pumping Plant Performance

$$\text{Annual Savings} = \left(1 - \frac{\text{Present Performance Rating}}{\text{Expected Performance Rating}}\right) \times \text{Present Annual Fuel Cost}$$

Assume adjustment of pump will bring performance rating to 81% from 72%

Expected Performance Rating = 81%

$$\frac{\text{Present Performance Rating}}{\text{Expected Performance Rating}} = \frac{72.0}{81.0} = 0.89$$

Annual Savings = (1 — 0.89) X \$4,149.60 = \$456.46

6. Feasibility of Improvement

Interest Rate = 14%

Cost Recovery Period (Loan Period) or Life of Repair — 1 yr.

Capital Recovery Factor (From Table 2) = 1.1400

Cost of Repair = $500 (might be cost of pumping plant performance test and pump adjustment)

Annualized Investment Cost = Investment Cost X Capital Recovery Factor (Improvement Cost)

Annualized Investment Cost = $500 X 1.1400 = $570

Evaluation of Feasibility

Annual Savings — Annualized Investment Cost

$456.46 — $570 = —$113.54

The improvement is not economically feasible because the difference between the annual savings and annualized investment cost is negative.

If a 2 year life of repair is used, step 6 would be as follows:

Capital Recovery Factor (From Table 2) = .6073

Annualized Investment Cost = $500 x .6073 = $303.65

Evaluation of Feasibility

Annual Savings — Annualized Investment Cost

$456.46 — $303.65 = $152.81

Since the difference between annual savings and annualized investment costs is positive, the improvement would be economically feasible with at least a 2 year cost recovery period.

Consider another example with the same initial conditions, but by spending $3,750 to replace the pump, the performance rating can be increased to 100%. This example starts at Step 5.

5. $\frac{\text{Present Performance Rating}}{\text{Expected Performance Rating}} = \frac{72.0}{100} = 0.72$

Annual Savings = (1 — 0.72) X $4,149.60 = $1,161.89

6. Feasibility of Repair

Interest Rate = 14%

Cost Recovery Period = 5 years

Capital Recovery Factor (From Table 2) = .2913

Cost of Repair = $3,750

Annualized Investment Cost = $3,750 X .2913 = $1,092.38

Evaluation of Feasibility

Annual Savings — Annualized Investment Cost

$1,161.89 — $1,092.38 = $69.51

The pump replacement is economically feasible since the difference between savings and cost is positive. Using a lower interest rate or longer cost recovery period will increase the difference between the annual savings and cost.

Another question that might be asked is, "How much can I spend for improvement if I know the interest rate and cost recovery period (loan period)?" The procedure for answering this question is illustrated using the information from the preceeding example.

Interest rate = 14%

Cost Recovery Period = 5 years

Capital Recovery Factor (from Table 2) = .2913

$$\text{Maximum Improvement Cost} = \frac{\text{Annual Savings}}{\text{Capital Recovery Factor}}$$

or "Break-even"

$$\frac{\$1,161.89}{.2913} = \$3,988.63$$

The method for evaluating feasibility of making pumping plant improvements provides information to help decision making. Other factors that must also be considered include a cash flow analysis to determine financial feasibility, income taxes-investment credit, inflation, risk, and uncertainty. The evaluation method assumes that the annual energy savings are equal each year. Changing conditions may result in different savings from year to year. For example, pumping considerable sand in the water can cause pump wear that will result in a rapid change in performance rating. Changing

water levels will also impact performance rating. In addition to increased energy costs, poor pumping plant performance may result in pumping rates below those possible with a given well. Reduced pumping rates may mean a reduction in irrigated acreage or crop yields. Therefore, improved pumping plant performance may help maintain or increase the pumping rate with a corresponding impact on yields or acres irrigated.

SUMMARY

A pumping plant test and the Nebraska Plant Performance Criteria provide a useful tool to evaluate pumping plant performance. An economic evaluation, using an amortization technique, of making pumping plant improvement can be made if the following information is available: pumping plant test data, performance rating, estimated improvement cost, an interest rate, and cost recovery period. Pumping plant improvements will be most critical when (a) there is a large lift (b) the discharge pressure is high (c) large quantities of water are pumped and (d) energy costs are increasing. Energy cost may constitute from 10 to 35% of the total irrigation costs. Therefore, with continued high energy costs, maintaining peak pumping plant performance will be important to all irrigators.

ACKNOWLEDGMENT

The suggestions and advice of Douglas Duey, Extension Economist—Farm Management, in selecting a method to evaluate economic feasibility, are appreciated.

Table 1. Nebraska pumping plant performance criteria.

Energy source	whp-hr/unit of energy[a/]	Energy unit
Diesel	12.5	gallon
Propane	6.89	gallon
Natural gas	61.7	1000 ft^3 (mcf)
Electricity	0.885	kW-hr
Gasoline	8.66	gallon

[a/] whp-hr (water horsepower-hours)/unit of energy is the performance of the pumping plant as a complete unit—power unit, drive, and pump. The values are based on a field pump efficiency of 75%.

WORKSHEET FOR EVALUATING THE ECONOMIC FEASIBILITY OF PUMPING PLANT PERFORMANCE IMPROVEMENT

Information from Pumping Plant Test

Pumping Rate _____ GPM

Lift _____ feet

\+ \+

Discharge Pressure _____ psi x 2.31 = _____ feet

Total Pumping Head = _____ feet

Energy Type _____

Energy Use _____ unit of energy/hour

Energy Cost _____ $/unit of energy

Acres Irrigated _____ acres

Water Applied _____ inches

Calculations

1. Water-horsepower (whp) = $\frac{\text{Pumping Rate, GPM} \times \text{Total Pumping Head, ft}}{3960}$

$$\text{whp} = \frac{\text{GPM (}\quad\text{)} \times \text{feet (}\quad\text{)}}{3960} = _____$$

2. Pumping Plant Performance = $\frac{\text{whp}}{\text{energy use or fuel consumption}}$

$$\text{Performance} = \frac{\text{whp (}\quad\text{)}}{\text{units of energy/hour (}\quad\text{)}}$$

= _____ whp-hr/unit of energy

3. Performance Rating = $\frac{\text{Actual Performance}}{\text{Performance Criteria (From Table 1)}} \times 100$

$$\text{Rating} = \frac{\text{whp-hr/unit of energy (}\quad\text{)}}{\text{whp-hr/unit of energy (}\quad\text{)}} \times 100$$

= _____ %

4. Total Annual Energy Cost

Pumping Rate, ac. in./hr = $\frac{\text{GPM (_____)}}{450}$ = _____ ac. in./hr

Energy Cost/Acre Inch =

$$\frac{\text{Energy Use, (units of energy/hr) X Energy Cost, (\$/unit of energy)}}{\text{Pumping Rate, (ac. in./hr)}}$$

Energy Cost/Acre Inch =

$$\frac{\text{Units of energy/hr (_____) X \$/unit of energy (_____)}}{\text{ac. in./hr(_____)}}$$

= $ _____ per acre inch

Total Annual Energy Cost =

Acres Irrigated X Average Total Irrigation Applied, In. X Energy cost/ac. in.

Total Annual Energy Cost = _____ acres x _____ inches x $_____ ac. in.

5. Potential Annual Savings by Improving Pumping Plant Performance

$$\text{Annual Savings} = \left(1 - \frac{\text{Present Performance Rating}}{\text{Expected Performance Rating}}\right) \text{X (Present Ann. Fuel Cost)}$$

Expected Performance Rating after improvement _____ %

$$\text{Annual Savings} = \left(1 - \frac{(_____)}{(_____)}\right) \text{X \$/year } _____$$

= $ _____

6. Economic Feasibility of Improvement

Interest Rate = _____ %

Cost Recovery Period, Loan Period, or Life of Repair = _____ years

Capital Recovery Factor = _____
(From Table 2)

Cost of Repair = $_____

Annualized Investment Cost =

Investment Cost (Improvement Cost) X Capital Recovery Factor

Annualized Investment Cost = $ _____ X _____

= $ _____

Feasibility Evaluation

Annual Savings - Annualized Investment Cost

$ _____ — $ _____ = $ _____

(The improvement is economically feasible if this number is positive.)

7. Maximum that can be invested for improvement.

$$\text{Maximum Improvement Cost} = \frac{\text{Annual Savings}}{\text{Capital Recovery Factor}}$$

$$\text{Maximum Improvement Cost} = \frac{(_____)}{(\quad)} = \$ _____$$

Table 2. Capital recovery factors (CRF) or amortization table at given interest rates and time periods.

Cost recovery period, years	Interest rate, percent										
	8	9	10	11	12	13	14	15	16	17	18
1	1.0800	1.0900	1.1000	1.1100	1.1200	1.1300	1.1400	1.1500	1.1600	1.1700	1.1800
2	.5608	.5685	.5762	.5839	.5917	.5995	.6073	.6151	.6230	.6308	6387
3	.3881	.3951	.4021	.4092	.4163	.4235	.4307	.4380	.4453	.4526	.4599
4	.3019	.3087	.3155	.3223	.3292	.3362	.3432	.3503	.3574	.3645	.3717
5	.2505	.2571	.2638	.2706	.2774	.2843	.2913	.2983	.3054	.3126	.3198
6	.2163	.2229	.2296	.2364	.2432	.2502	.2572	.2642	.2714	.2786	.2859
7	.1921	.1987	.2054	.2122	.2191	.2261	.2332	.2404	.2476	.2549	.2624
8	.1740	.1807	.1874	.1943	.2013	.2084	.2156	.2229	.2302	.2377	.2452
9	.1601	.1668	.1736	.1806	.1877	.1949	.2022	.2096	.2171	.2247	.2324
10	.1490	.1558	.1627	.1698	.1770	.1843	.1917	.1993	.2069	.2147	.2225

$$\text{CRF} = \frac{i\,(i+1)^n}{(i+1)^n - 1}$$

where i = *interest rate*

n = cost recovery period, years

Annualized investment cost = total investment cost x CRF

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