IRRIGATION MANAGEMENT SERIES

EVALUATING PUMPING PLANT EFFICIENCY

Using On-Farm Fuel Bills

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Every farmer needs to make a profit in order to continue farming. Traditionally, farming has not made a large return on investment, so when production costs rise in comparison to crop price and/or yield, profits can quickly turn into deficits. Irrigators are also subject to this economic reality, so they also need to evaluate the cost-effectiveness of production inputs. One component is irrigation fuel. The irrigator should know whether irrigation costs are reasonable and whether irrigation is paying its way.

The irrigation fuel or energy bill is composed of two parts. The first is related to pumping plant performance and the second to crop and irrigation management.

Total fuel bill = Pumping Cost/ Volume × Volume Applied

Reducing the total volume applied reduces the fuel bill proportionately so if the amount of water applied is minimized with good irritation scheduling and high application efficiency, the fuel bill will also be reduced by a similar amount. How this is done is the subject of other extension bulletins and will not be discussed here.

The major factors that influence the pumping cost per volume are: pumping plant efficiency and TDH or total dynamic head, which is the total hydraulic resistance against which the pump must operate. Well efficiency is also a factor, but it is largely determined by design and construction factors that were used during the drilling and development processes. Many wells would produce a greater flow with less drawdown if the screen, gravel pack and development procedure had been better designed, but little can be done to improve the efficiency of a poorly constructed well.

Performance evaluations indicate that, on average, irrigation pumping plants in Kansas use about 40 percent more fuel than necessary if a properly sized, adjusted and maintained pumping plant were used. Obviously, some are much worse and others much better. Causes of excessive fuel use include:

1. Poor pump selection. Pumps are designed for a particular discharge, head and speed. If used outside a fairly narrow range in head, discharge and speed, the efficiency is apt to suffer. Some pumps were poor choices for the original condition, but changing conditions such as lower water levels or changes in pressure also cause pumps to operate inefficiently.
2. Pumps out of adjustment. Pumps need adjustment from time to time to compensate for wear.
3. Worn-out pumps. Pumps also wear out with time and must be replaced.
4. Improperly sized engines or motors. Power plants must be matched to the pump for efficient operation. Engine or motor loads and speed are both important to obtain high efficiency.
5. Engines in need of maintenance and/ or repair.
6. Improperly matched gear heads. Gear head pump drives must fit the load and speed requirements of the pump and engine.

Pumping plant performance evaluations can be obtained by hiring a consulting firm or contractor to take the measurements, but many farmers are reluctant to spend money to find out if something is wrong. Energy costs, however, can represent a significant portion of the production cost for a crop. The following will help an irrigator analyze irrigation fuel or energy bills to see if they are within reason considering the pumping conditions and price of fuel or energy.

Irrigation pumping energy requirements can be estimated using the Nebraska Performance Criteria shown in Table 1. The Nebraska criteria is a guideline for a performance of a properly designed and maintained pumping plant. Some pumping plants will exceed this criteria, but most will not.

If this estimate indicates low pumping plant efficiency, then hiring a firm to repair or replace the pumping plant may be justified.

The irrigator needs the following information to make such an estimate:

1) Acres irrigated
2) Discharge rate
3) Total dynamic head
4) Total application depth
5) Total fuel bill
6) Fuel price/unit

STEP 1: DETERMINE WATER HORSEPOWER

Water horsepower (WHP) is the amount of work done on the water and is calculated by

WHP = TDH (GPM)/3960.

where:

GPM = discharge rate in gallons per minute

TDH = total dynamic head (in feet)

TDH is usually estimated by adding total pumping lift and pressure at the pump. Since pressure is usually measured in PSI, convert PSI to feet by multiplying PSI × 2.31 (see conversions in Table 2).

STEP 2: CALCULATE HOURS OF PUMPING

HR = D (Ac)/(GPM/450)

where:

HR = Hours of pumping

D = Depth of applied irrigation water (inches)

Ac = Acres irrigated

GPM = discharge rate in gallons/minutes

450 = Constant (see conversion in Table 2)

STEP 3: ESTIMATE HOURLY NPC FUEL USE

FU = WHP/NPC

where:

FU = Hourly fuel use using the Nebraska criteria

WHP = Water Horsepower from Step 1

NPC = Nebraska Performance Criteria (Table 1)

STEP 4: ESTIMATE SEASONAL NPC FUEL COST

SFC = FU × HR × Cost

where:

SFC = Seasonal Fuel Cost if the pumping plant was operating at NPC

HR = Hours of operation from Step 2

Cost = $/Fuel Unit

STEP 5: DETERMINE EXCESS FUEL COST

EFC = AFC – SFC

where:

EFC = Excess Fuel Cost (in dollars)

AFC = Actual Fuel Cost (in dollars)

SFC = Estimated Seasonal Fuel Cost using NPC (in dollars)

STEP 6: CALCULATE ANNUALIZED REPAIR COST

ARC = INVEST × CRF

where:

ARC = Annualized Repair Cost

INVEST = Investment required to repair or upgrade pumping plant

CRF = Capital Recovery Factor (Table 3)

The excess fuel cost may be thought of as the annual payment to cover the cost of a pumping plant upgrade or repair. Repair costs can be annualized by using capital recovery factors (CRF). If the annualized repair cost for the interest rate and return period selected is less than the excess fuel cost, the investment in repair is merited.

This procedure is an indicator of total pump plant performance. It does not indicate the source of the excessive fuel use, but pumping plant tests in Kansas have generally shown that poor performance is generally the fault of the pump. The low efficiency may be due to excessive pump clearance, worn impellers, or changes in pumping conditions since the pump was installed. However, engines and gear heads can also be problems.

Table 1. Nebraska Performance Criteria for Pumping Plants

Energy Source	WHP–HRS per Unit of Fuel
Diesel	12.50 per gallon
Propane	6.89 per gallon
Natural Gas	61.7 per MCF
Electricity	0.885 per KWH (kilowatt-hour)

Table 2. Useful Irrigation Conversions

1 psi (pounds per square inch) = 2.31 feet of head

1 acre-inch/hour = 450 gallons/minute

Table 3. Selected Capital Recovery Factors (CRF)

Length of Loan or Length of Useful Life	Annual Interest Rate (%)				
Years	5	7	10	12	15
·2	.5378	.5531	.5712	.5917	.6151
3	.3672	.3811	.4021	.4163	.4380
4	.2820	.2952	.3155	.3292	.3503
5	.2310	.2439	.2638	.2774	.2983
7	.1728	.1856	.2054	.2191	.2404
10	.1295	.1924	.1627	.1770	.1993
15	.0963	.1098	.1315	.1468	.1710

Example Farm Problem:

Acreage:	150 acres
Pumping Lift:	300 feet
System Pressure:	22 psi
System Discharge Rate:	1200 gpm
Total Irrigation Application:	24 inches per acre
Fuel Type: Natural Gas	Price: $ 3.50 per MCF
Total Fuel Bill:	$ 11500

Step 1: Determine Water Horsepower

WHP = TDH × (GPM)/3960

= (300 + 22 × 2.31) × (1200)/3960

= 106 WHP

Step 2: Calculate Hours of Pumping

HR = D(Ac)/GPM/450)

= (24) (150)/(1200/450)

= 1348 hrs.

Step 3: Estimate Hourly NPC Fuel Use

FU = WHP/NPC

= 106/61.7

= 1.72 MCF/Hr.

Step 4: Estimate Seasonal NPC Fuel Cost

SFC = FU × Hr × Cost

= 1.72 × 1348 × 3.50

= $8115

Step 5: Determine Excess Fuel Cost

EFC = AFC–SFC

= 11500–8115

= $3385

Step 6: Calculate Annualized Repair Cost

Estimate of pump repair: $6000

Desired CRF using 3 years and 7% interest

from Table 3: CRF = 0.3811

ARC = INVEST × CRF

= 6000 (0.3811)

= $2287

Your Farm: Pumping Plant #1

Acreage:	________ Ac
Pumping Lift:	________ Ft
System Pressure:	________ PSI
System Discharge Rate:	________ GPM
Total Irrigation Application:	________ Inches
Fuel Type: Price	________
Total Fuel Bill:	$ ________

Step 1: Determine Water Horsepower

WHP = TDH × GPM/3960

= (_____ ft + _____ PSI × 2.31) × _____ GPM/3960

= ________________ WHP

Step 2: Calculate Hours of Pumping

HR = D (Ac)/(GPM/450)

HR = _____ in × _____ Ac/ (_____ GPM/450)

= ________ Hours

Step 3: Estimate Hourly NPC Fuel Use

FU = WHP/NPC

= _____ / _____

= __________ /Hr.

Step 4: Estimate Seasonal NPC Fuel Cost

SFC = FU × Hr × Cost

= _____ × _____ × _____

= $ ________________

Step 5: Determine Excess Fuel Cost

EFC = AFC–SFC

= $ _____ – $ _____

= $ ________________

Step 6: Calculate Annualized Repair Cost

Repair Estimate $ ____________

ARC = INVEST × CRP

= $ _____ × _____

= $ ________________

$2287 is less than $3385, so the investment in repair of the pumping plant would be merited. The excess fuel use could be divided by the CRF (example $3385/.3811 = $8882) to indicate the amount you could afford to spend in upgrading the pumping plant. Table 1. Nebraska Performance Criteria for Pumping Plants

Your Farm: Pumping Plant #2

Acreage: ______________ Ac
Pumping Lift: ______________ Ft
System Pressure: ______________ PSI
System Discharge Rate: ______________ GPM
Total Irrigation Application: ______________ Inches
Fuel Type: Price ______________
Total Fuel Bill: $ ______________

Step 1: Determine Water Horsepower

WHP = TDH × GPM/3960
= (_____ ft + _____ PSI × 2.31) × _____ GPM/3960
= ______________ WHP

Step 2: Calculate Hours of Pumping

HR = D (Ac)/(GPM/450)
HR = _____ in × _____ Ac/ (_____ GPM/450)
= ________ Hours

Step 3: Estimate Hourly NPC Fuel Use

FU = WHP/NPC
= _____ / _____
= ________ /Hr.

Step 4: Estimate Seasonal NPC Fuel Cost

SFC = FU × Hr × Cost
= _____ × _____ × _____
= $ ______________

Step 5: Determine Excess Fuel Cost

EFC = AFC–SFC
= $ _____ – $ _____
= $ ______________

Step 6: Calculate Annualized Repair Cost

Repair Estimate $ __________
ARC = INVEST × CRP
= $ _____ × _____
= $ ______________

Your Farm: Pumping Plant #3

Acreage: ______________ Ac
Pumping Lift: ______________ Ft
System Pressure: ______________ PSI
System Discharge Rate: ______________ GPM
Total Irrigation Application: ______________ Inches
Fuel Type: Price ______________
Total Fuel Bill: $ ______________

Step 1: Determine Water Horsepower

WHP = TDH × GPM/3960
= (_____ ft + _____ PSI × 2.31) × _____ GPM/3960
= ______________ WHP

Step 2: Calculate Hours of Pumping

HR = D (Ac)/(GPM/450)
HR = _____ in × _____ Ac/ (_____ GPM/450)
= ________ Hours

Step 3: Estimate Hourly NPC Fuel Use

FU = WHP/NPC
= _____ / _____
= ________ /Hr.

Step 4: Estimate Seasonal NPC Fuel Cost

SFC = FU × Hr × Cost
= _____ × _____ × _____
= $ ______________

Step 5: Determine Excess Fuel Cost

EFC = AFC–SFC
= $ _____ – $ _____
= $ ______________

Step 6: Calculate Annualized Repair Cost

Repair Estimate $ __________
ARC = INVEST × CRP
= $ _____ × _____
= $ ______________

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