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 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 X Volume Applied

Reducing the total volume applied reduces the fuel bill proportionately — if the amount of water applied is minimized with good irrigation 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: fuel price, pumping plant efficiency and total dynamic head (TDH). TDH 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. Well efficiency can also be affected by incrustation of the well screens that might occur due to chemical reactions between the well screen and water and/or biological processes. The former may require aggressive cleaning to remove, while the latter might be controlled by shock chlorination.

Performance evaluations indicate that, on average, irrigation pumping plants in Kansas use about 30 percent more fuel than necessary if not properly sized, adjusted and maintained. For example, a 1990 Kansas study (KGA, 1990) (Table 1a) found pumping plant performance ratings ranging from 15 to 120 percent of the Nebraska Pumping Plant Performance Criteria (NPC). NPC values are accepted industry estimate of the energy consumption for a properly designed and operated pumping plant. Obviously, some are much worse and others much better. Table 1b shows the test data by energy source.

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. 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, as discussed previously, can be estimated using NPC and are shown in Table 2. Some pumping plants may 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) x (GPM ÷ 3960)

where:

GPM = discharge rate in gallons per minute

TDH = total dynamic head (in feet)

3960 = Constant (see conversion in Table 3)

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) x (2.31) (see conversions in Table 3).

STEP 2: CALCULATE HOURS OF PUMPING

HR = (D) x (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 3)

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 2)

STEP 4: ESTIMATE SEASONAL NPC FUEL COST

SFC = (FU) x (HR) x (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) x (CRF)

where:

ARC = Annualized Repair Cost

INVEST = Investment required to repair or upgrade pumping plant

CRF = Capital Recovery Factor (see Table 4)

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

Table 1a. Summary of Well and Pumping Plant Performance Testing Data from the Dakota Aquifers Program, (MacFalane, P.A., et.al., 1990)

Area	Static Level Ft.	Dynamic Level Ft.	Well Yield Gpm	NPC Rating
Southwest	240 (70-330)	277 (160-430)	774 (170-1230)	85 (40-120)
West Central	109 (30-330)	142 (40-280)	668 (400-1050)	81 (30-115)
North Central	49 (25-100)	98 (40-155)	432 (275-860)	61 (15-110)

Notes:

1. Values are average to the nearest whole number except for range, note 2.

2. Range of values in () to nearest five units.

Table 1b. Summary of Pumping Plant Performance Evaluation by Energy Source from the Dakota Aquifer Program (MacFarlane, P.A., et. al., 1990)

Energy Source	No. of Wells	Average (%)	Quartile average (%)			
			1st	2nd	3rd	4th
Natural Gas	32	85.5	112.1	96.1	80.3	53.4
Electric	18	77.4	107.3	87.0	69.9	45.4
Diesel	17	69.9	97.8	81.2	66.4	34.2
Propane	4	47.3	—	—	—	—

71 total - Weighted average 77.3%

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.

Kansas State Research and Extension has computer software available to aid in evaluating pumping plant efficiency. The software program, FuelCost, is available via the Web at ***www.oznet.ksu.edu/mil***.

Example Farm Problem:

Acreage: 122 acres
Pumping Lift: 300 feet
System Pressure: 22 psi
System Discharge Rate: 800 gpm
Total Irrigation Application: 18 inches per acre
Fuel Type: Natural Gas Price: $8.00 per MCF
Total Fuel Bill: $19,700

Step 1: Determine Water Horsepower
WHP = (TDH) x (GPM ÷ 3960)
= [300 + (22 x 2.31)] x (800 ÷ 3960)
= 71 Water Horsepower

Step 2: Calculate Hours of Pumping
HR = (D) x (AC) ÷ (GPM ÷ 450)
= (18) x (122) ÷ (800 ÷ 450)
= 1,235 hours

Step 3: Estimate Hourly NPC Fuel Use
FU = (WHP) ÷ (NPC)
= (71) ÷ (62.7)
= 1.15 MCF/hour

Step 4: Estimate Seasonal NPC Fuel Cost
SFC = (FU) x (Hr) x (Cost)
= (1.15) x (1,235) x ($8.00)
= $11,362

Step 5: Determine Excess Fuel Cost
EFC = (AFC) – (SFC)
= ($19,700) – ($11,362)
= $8,338

Step 6: Calculate Annualized Repair Cost
Estimate of REPAIR cost: $12,000
Desired CRF using 3 years and 7% interest
from Table 4: CRF = 0.3811
ARC = (REPAIR) x (CRF)
= ($12,000) x (0.3811)
= $4,573

Since $4,573 is less than $8,338, the investment in repair of the pumping plant would be merited. The excess fuel use could be divided by the CRF (example $8,347/.3811 = $21,902) to indicate the amount you could afford to spend in upgrading the pumping plant to meet Nebraska Pumping Plant Performance Criteria (NPC).

This analysis can be completed for your farm using the following charts. However, a computer program called FuelCost is available to facilitate estimating pumping plant efficiency. The program is available on the Mobile Irrigation Lab (MIL) Web site at *www.oznet.ksu.edu/mil*.

Table 2. Nebraska Performance Criteria for Pumping Plants

Energy Source	WHP-HRS per Unit or 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 3. Useful Irrigation Conversions

1 psi (pounds per square inch) = 2.31 feet of head
1 acre-inch/hour = 450 gallons/minute
1 horsepower = 33,000 ft-lbs/min
1 gallon of water = 8.33 pounds
$3960 = \frac{33,000}{8.33}$

Table 4. Selected Capital Recovery Factors (CRF)

Length of Load or Length of Useful Life Years	Annual Interest Rate (%)				
	5	7	10	12	15
2	.5378	.5531	.5712	.5917	.6151
3	.3672	.3811	.4021	.4163	.4380
4	.2820	.2820	.3155	.3292	.3503
5	.2310	.2310	.2638	.2774	.2983
7	.1728	.1728	.2054	.2191	.2404
10	.1295	.1295	.1627	.1770	.1993
15	.0963	.0963	.1315	.14	.1710

Your Farm: Pumping Plant #l

Acreage: ____________________ Ac
Pumping Lift: _________________ Ft
System Pressure: _____________PSI
System Discharge Rate: ______ GPM
Total Irrigation Application: ____ In.
Fuel Type: ________ Price: ________
Total Fuel Bill: $ _________________

Step 1: Determine Water Horsepower
WHP = (TDH) x (GPM ÷ 3960)
= [___ ft + (___PSI x 2.31)] x (___ GPM ÷ 3960)
= ___ WHP

Step 2: Calculate Hours of Pumping
HR = (D) x (AC) ÷ (GPM ÷ 450)
= (____ in) x (____ AC) ÷ (____ GPM ÷ 450)
= ______ hours

Step 3: Estimate Hourly NPC Fuel Use
FU = (WHP) ÷ (NPC)
= (_______) ÷ (_______)
= _______ MCF/hour

Step 4: Estimate Seasonal NPC Fuel Cost
SFC = (FU) x (Hr) x (Cost)
= (_______) x (_______) x ($_______)
= $__________

Step 5: Determine Excess Fuel Cost
EFC = (AFC) – (SFC)
= ($_________) – ($__________)
= $_________

Step 6: Calculate Annualized Repair Cost
REPAIR Estimate $___________
ARC = (REPAIR) x (CRF)
= ($_________) x (________)
= $_________

Your Farm: Pumping Plant #2

Acreage: ____________________ Ac
Pumping Lift: _________________ Ft
System Pressure: _____________PSI
System Discharge Rate: ______ GPM
Total Irrigation Application: ____ In.
Fuel Type: ________ Price: ________
Total Fuel Bill: $ _________________

Step 1: Determine Water Horsepower
WHP = (TDH) x (GPM ÷ 3960)
= [___ ft + (___PSI x 2.31)] x (___ GPM ÷ 3960)
= ___ WHP

Step 2: Calculate Hours of Pumping
HR = (D) x (AC) ÷ (GPM ÷ 450)
= (____ in) x (____ AC) ÷ (____ GPM ÷ 450)
= ______ hours

Step 3: Estimate Hourly NPC Fuel Use
FU = (WHP) ÷ (NPC)
= (_______) ÷ (_______)
= _______ MCF/hour

Step 4: Estimate Seasonal NPC Fuel Cost
SFC = (FU) x (Hr) x (Cost)
= (_______) x (_______) x ($_______)
= $__________

Step 5: Determine Excess Fuel Cost
EFC = (AFC) – (SFC)
= ($_________) – ($__________)
= $_________

Step 6: Calculate Annualized Repair Cost
REPAIR Estimate $___________
ARC = (REPAIR) x (CRF)
= ($_________) x (________)
= $_________

Your Farm: Pumping Plant #3

Acreage: ____________________ Ac
Pumping Lift: _________________ Ft
System Pressure: _____________PSI
System Discharge Rate: ______ GPM
Total Irrigation Application: ____ In.
Fuel Type: ________ Price: ________
Total Fuel Bill: $ _________________

Step 1: Determine Water Horsepower
WHP = (TDH) x (GPM ÷ 3960)
= [___ ft + (___PSI x 2.31)] x (___ GPM ÷ 3960)
= ___ WHP

Step 2: Calculate Hours of Pumping
HR = (D) x (AC) ÷ (GPM ÷ 450)
= (____ in) x (____ AC) ÷ (____ GPM ÷ 450)
= ______ hours

Step 3: Estimate Hourly NPC Fuel Use
FU = (WHP) ÷ (NPC)
= (_______) ÷ (_______)
= _______ MCF/hour

Step 4: Estimate Seasonal NPC Fuel Cost
SFC = (FU) x (Hr) x (Cost)
= (_______) x (_______) x ($_______)
= $__________

Step 5: Determine Excess Fuel Cost
EFC = (AFC) – (SFC)
= ($_________) – ($__________)
= $_________

Step 6: Calculate Annualized Repair Cost
REPAIR Estimate $___________
ARC = (REPAIR) x (CRF)
= ($_________) x (________)
= $_________

This material is supported in part by Kansas Water Plan funds through the Kansas Water Office and USDA Project 05-34296-15666 and the Ogallala Initiative.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

L885 rev. July 2006

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